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Sustainable City 2022

The Sustainable City XVI

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Sixteenth International Conference on Urban Regeneration and Sustainability

SUSTAINABLE CITY XVI

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Preface

The present volume contains a selection of the papers presented at the 16th International Conference on Urban Regeneration and Sustainability (Sustainable City 2022), organised by the Wessex Institute of Technology. This conference was originally scheduled to take place in Rome, in Italy, but subsequently had to be held online due to political and military situation in Europe and some remaining steps of the COVID-19 pandemic.

Sustainable City 2022 follows a series of very successful meetings that started in Rio (2000), followed by Segovia (2002), Siena (2004), Tallinn (2006), Skiathos (2008), A Coruña (2010), Ancona (2012), Kuala Lumpur (2013), Siena (2014), Medellin (2015), Alicante (2016), Seville (2017) and Valencia (2019). Editions of 2020 and 2021 was programmed in Rome and Bilbao respectively but took place online due to the difficulties and prohibitions for travelling generated by the pandemic. Nevertheless, both the in person and the online version of the events have attracted a large number of delegates as well as papers and presentations of high quality; this testifies to the worldwide interest in and success of the conference series.

Urban areas result in a series of environmental challenges varying from the consumption of natural resources and the subsequent generation of waste and pollution, contributing to the development of social and economic imbalances. According to current trends, the population is concentrating in urban areas that continue to grow all over the world. Old and new problems tend to become more acute and require the development of innovative solutions to create liveable urban areas without endangering our common future.

The task of researchers is to improve the capacity to manage human activities, pursuing welfare and prosperity in the urban environment. Any investigation or planning in a city ought to consider the relationships between the parts and their connections with the living world. The dynamics of its networks (flows of energy-matter, people, goods, information and other resources) are fundamental for an understanding of the evolving nature of today's cities.

Coastal areas and coastal cities are an important issue at the conference as they have some specific features. Their strategic location facilitates transportation and the development of related activities, but this requires the existence of large ports, with the corresponding increase in maritime and road traffic and all of the inherent negative effects, and can be directly affected by the rise in sea level. This requires the development of well-planned and managed urban environments, not only for

reasons of efficiency and economics but also to avoid inflicting environmental degradation that causes the deterioration of natural resources, quality of life and human health.

Urban agriculture and food sovereignty are crucial issues that have been included in the conference due to their impact on city life. The scale of modern food production has created and exacerbated many vulnerabilities and the feeding of cities is now infinitely more complex. In the last few years, there has been a rapid expansion in initiatives and projects exploring innovative methods and processes for sustainable food production. The majority of these projects are focused on providing alternative models that shift the power back from the global food system to communities and farmers improving social cohesion, health and wellbeing. These initiatives have demonstrated that urban agriculture has the potential to transform our living environment towards ecologically sustainable and healthy cities.

Large cities represent a fertile ground for architects, engineers, city planners, social and political scientists, and other professionals able to conceive new ideas and time them according to technological advances and human requirements. Their works are essential in order to help public policies progress and become more committed to environmental challenges.

The contents of the book corresponds to a very wide ranges of topics, among them: Architectural issues, environmental management, planning for risk, climate change and natural hazards, the community and the city, urban transportation and planning, energy conversion and generation, urban agriculture and food sovereignty, city/waterfront interaction, waste management, cultural heritage sites and urban and rural areas. So it supposes an important addition to the scientific literature in this field.

For this reason, the papers contained in this book, as well as those from previous conferences since 2000, have been archived in the eLibrary of the Wessex Institute (http://www.witpress.com/elibrary) where they are permanently accessible to the international scientific community.

The editors wishes to acknowledge the support of the authors, the members of the International Scientific Advisory Committee (ISAC), the referees, Marta Graczyk, the conference co-ordinator, as well as the WIT Press staff and Isabelle Rham, in particular.

Finally, the editors and ISAC members wish to honour the memory of the late Professor Carlos Brebbia, founder of Wessex Institute, who established this series of meetings having foreseeing its impact and appeal.

The Editors, 2022

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SECTION 1
ARCHITECTURAL ISSUES

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CREATING INCLUSIVE COMMERCIAL SPACES FOR WOMEN IN BAHRAIN

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ABSTRACT
The built environment should ideally respond to the needs of users from different demographic factors and backgrounds, which is why the design approach of inclusive design is increasingly relevant. One of the different demographic factors includes gender, and creating gender inclusive designs is crucial as historically spaces have been centered around the needs of men. This research investigates inclusivity in commercial spaces for women in Bahrain. A rating system is created based on the theoretical background and the needs of women in Bahrain, considering four main parameters. The rating system is then used to evaluate the inclusivity of commercial spaces in Bahrain, through applying it on Segafredo Café located in Riffa, Bahrain as a local case study. The case study received a rating of 73.3% indicating good performance in its inclusivity for women. While the café was suitable overall in terms of spatial layout, circulation, and furniture, the main criteria that were lacking were in the provision of facilities that cater towards specific groups, such as women with infants, pregnant women, etc.
Keywords: inclusive design, rating system, commercial spaces, Bahrain.

1 INTRODUCTION

The provision of a built environment that responds to the needs of people from all backgrounds is becoming an essential aspect of architecture and interior design. The built environment must be able to be utilized by people from a wide variety of demographic groups [1]. This results in the approaches of inclusive design and universal design becoming increasingly relevant, which are design approaches focusing on designing built environments that accommodate and include people from all backgrounds [1].

One of the ways in which built environments can be more inclusive is by being inclusive for women. Historically, most of the built environment has been built and dominated by men, and centered around the requirements of a male breadwinner [2]. This resulted in a lack of inclusive spaces for women, and not realizing and meeting the basic and essential needs of women, thus resulting in women being excluded from a lot of spaces in the built environment [3]. It is crucial to include women in decision making processes and to involve them in the process of design (by hiring and collaborating with female architects and interior designers), as well as to encourage the participation of local women in the different stages of the design of the spaces in the built environment [4], [5]. This research investigates inclusivity in commercial spaces for women in Bahrain.

2 THEORETICAL BACKGROUND

2.1 Importance of inclusive design

The built environment should be designed to be accommodating to the needs of people from all backgrounds at the most fundamental level [6], [7]. Architects and interior designers are recognizing the damage done by excluding and alienating the users of the built environment, making the design approaches of universal design and inclusive design increasingly relevant [8].

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Inclusive design approaches ensure that various demographic factors such as age, gender, cultural beliefs, and religion are taken into consideration [8]. Swain et al. [9] explain that through this approach, architects and interior designers can implement features and spatial components that ensure that the built environment responds to the needs of the users and makes them feel comfortable and welcome. These design approaches are not just limited to the fields relating to the design of the built environment (such as architecture and interior design), but they can also be implemented in numerous other design fields such as communication design, product design, and so on [10].

One of the issues with the existing built environment that the approach of inclusive design highlights is the lack of inclusivity for women in the built environment. Spain [2] explains that this issue is a result of the fact that throughout history, most of the built environment was dominated by men, and so the design of spaces was centered around their needs and requirements. Moreover, Spain [3] adds that using the needs of the male breadwinner as a basis for the design of the built environment resulted in a lack of inclusive spaces for women, and women being excluded.

2.2 Factors affecting women's use of space

Women experience and navigate the built environment differently from men; this is a result of gender inequalities that influence movement patterns, use of public services, participation in public spaces, modes of transport, and the lack of security and safety [2]–[4], [8], [11]. The result of this is the creation of spaces that do not consider the needs of women, making them feel excluded, alienated, and unwelcome. These factors are explained in the following sections.

2.2.1 Lack of security and safety

Women are generally much more likely to fear being a victim of assault than men, causing them to feel unsafe in "vulnerable" spaces [8]. Spaces that are not easily accessible, poorly lit, and lacking activity and natural surveillance can create an environment that does not make women feel welcome [8], [11].

2.2.2 Participation in male dominated spaces

It is common for commercial public spaces to be dominated by male users, considering that the design of spaces is typically centered around their needs [3], [11]. This can result in women avoiding the spaces as they feel unwelcome, and the spaces do not respond to their needs. One of the ways in which this issue can be tackled is by creating gradients of separation of genders, such as women friendly spaces, and women only spaces [8].

2.2.3 Movement patterns

Men and women have been historically believed to have different movement patterns. For example, in a lot of cultures, women are only expected to go out for significant reasons such as work or education, which leads to the design of a city only accounting for the movement patterns and circulation of women to these spaces [4]. Another example is the width of circulation routes: when circulation routes are narrower, they tend to be dominated by men and having men less likely to move or make room for women [11].

2.2.4 Use of public services

Although, men and women use public services differently, the spaces containing these services are usually designed centered around the needs of men only [2]. This leads to women being disadvantaged by design. For example, women typically take up more time in

washrooms, and when this is not considered, it can lead to frequent queues in the washrooms [11].

2.3 Research question

There is generally a lack of literature, information, and guidelines about gender inclusivity in spaces, which affects both theory and practice [8]. This is especially more prominent in the Middle East. As a result, this research investigates inclusivity in commercial spaces for women in Bahrain, by creating a rating system to evaluate the inclusivity of commercial spaces in Bahrain, and then using the rating system on a local case study. The research will contribute to the body of literature regarding gender inclusivity in Bahraini spaces.

3 RESEARCH METHODOLOGY

The nature of this research is exploratory as it investigates how to create guidelines for creating inclusive commercial interior spaces for women in Bahrain. The main research methodology applied was qualitative research. Firstly, a rating system to evaluate the inclusivity of spaces was created based on the theoretical background. Secondly, a local case study was chosen where the rating system can be used to evaluate the inclusivity of the case study for women.

The rating system was created by assessing the theoretical background and the needs of women in Bahrain, especially regarding the causes of exclusion (lack of safety and security, male dominated spaces, differing movement patterns, and difficultly in the use of public services). From this, four main parameters were defined:

1. Spatial layout: This parameter relates to providing women with different levels of privacy as needed, such as women friendly and women only zones. It considers aspects such as visual connection and transparency, lighting, and how vulnerable the spaces are.
2. Circulation: This parameter relates to providing women different access routes. It considers aspects such as if the space provides adequate circulation to allow all genders, and if the spaces intended for women only are able to be accessed privately.
3. Provision of amenities: This parameter relates to the provision of suitable amenities for women. It considers aspects such as the provision of washrooms, break rooms, and changing rooms.
4. Furniture and finishings: This parameter relates to how suitable the furniture and finishings are for women. It considers how accessible they are for women from different demographic groups.

A rating system was created based on these four parameters (Table 1). The rating system contains 14 statements relating to the four parameters that are used to evaluate the inclusivity of the space. Each statement can be awarded points from 1–5, 1 being the lowest (very poor application) and 5 being the highest (very good application). Some of the statements might not apply to that specific space (such as ramps not needed as the space uses only one level), in that case it will be given 0 weight, and the total will be adjusted. The applicable statements will be awarded points and the total out of 70 (in the case that all statements are applicable) will be calculated, and converted to a percentage. The percentage indicates how well the space performed: below 50% is poor, 50%–70% is satisfactory, 70%–90% is good, above 90% is very good.

The case study that is chosen is Segafredo Café located in Enma Mall in Riffa, Bahrain. The case study data is collected through direct observations during two visits in May 2022

Table 1: The rating system.

Criteria	Points (out of 5)
Spatial layout	
The spaces are not male dominated and intimidating	5
The spaces make women feel safe through transparency and visual connections	5
The spaces provide adequate lighting	5
The spaces provide natural surveillance	5
Circulation	
The circulation routes provide sufficient width to allow all genders to use them	5
There are separate circulation routes for women only spaces	5
Provision of amenities	
Washrooms for women are provided and of adequate size (no queues forming)	5
Breastfeeding rooms and changing rooms are provided	5
Praying areas for women are provided	5
Furniture and finishings	
The space uses non slippery flooring that is suitable for strollers, wheelchairs, etc.	5
The space provides infant chairs as an option	5
The furniture provided accommodates different body types and sizes	5
The space uses automated doors for more accessibility	5
The space provides ramps with the right slopes for strollers, wheelchairs, etc.	5
Total (out of 70)	70

(each visit lasted approximately 2 hours) and photographs in order to analyze the space and evaluate it using the rating system to determine how inclusive it is for women. Given the exploratory nature of the research, it is the most suitable method as qualitative methods are ideally used with exploratory researches.

4 FINDINGS AND DISCUSSION

Segafredo Café was visited during May 2022 in order to take notes from direct observations, as well as taking photos for visual support of the research. The café was analyzed according to the four parameters of the rating system, taking the 14 statements into consideration while taking notes and observations.

4.1 Analysis according to the four parameters

4.1.1 Spatial layout

The café consists of open areas with minimal divisions. The main division is between the indoor and outdoor area. The indoor area uses an open plan with transparency and lots of visual connections (Fig. 1 (left)). This provides natural surveillance and makes women feel secure. However, considering the Bahraini culture, some women might want zones that are more private as some form of division between genders.

Figure 1: The indoor (left) and outdoor (center and right) spaces [12]–[14]. The spaces are open and have visual connection between indoors and outdoors, providing natural surveillance. The lighting is adequate and the space is well lit.

The indoor area is family friendly and is not male dominated; it does not feel intimidating for women and rather is comfortable and welcoming for everyone. The outdoor area is used primarily by smokers, so it is often male dominated, as smoking is generally not socially acceptable for women in Bahrain. This creates an intimidating atmosphere and does not feel welcoming. Moreover, the smell of the cigarettes is very strong and unpleasant. So overall, the outdoor space often excludes women from using it and enjoying the outdoor view. The café uses adequate lighting in both the indoor and outdoor areas, and is well maintained, contributing more to the feeling of safety and security.

4.1.2 Circulation

The main circulation routes are of adequate width, and allow everyone to move freely. However, some of the café's furniture is tightly placed which can result in difficulty moving around (Fig. 2 (right)). This is especially important for women who have different body types that need the extra space such as pregnant women. The tight placement can also cause difficulty in movement for women who might not want to be in close proximity with men due to cultural reasons. Considering that the outdoors can be male dominated with women

Figure 2: Clear and direct main circulation route in the café with the entrance to the outdoor circled (left and center) [15], [16]. Tight placement between some of the furniture (right) [17].

using the indoor space more commonly, the circulation routes are accessible for women and direct since the main entrance is to the indoor space (rather than having to go through the outdoor first then indoor) (Fig. 2 (left and center)).

4.1.3 Provision of amenities

Since the café is located within a mall, it is not directly connected to any washrooms or other amenities. So this parameter does not have weight in this case study. Regardless, there are washrooms for women in the mall provided close by (approximately 15 m away). Moreover, there is a prayer area for women located on the second floor of the mall, which is not in close proximity but still very accessible.

4.1.4 Furniture and finishings

The café uses a variety of different seating options which is good for being useable by women of different body types. The furniture differs in height, width, and materials (Fig. 3). The majority of the furniture provides sufficient dimensions even for women who might need more space. The furniture uses enough padding to be comfortable to be used for longer periods, such as for studying, in addition to arm rests for added comfort. One of the furniture is a sofa that extends for several tables (as shown in Fig. 2 (right)) which more than one group of customers may share. The tables for each group are in proximity which may lead to some women avoiding them if there are men customers in the adjacent table, particularly women who prefer a certain degree of division between genders. Moreover, the café does not provide chairs for infants.

Figure 3: A variety of furniture with different heights, widths, and materials [12], [18]. The different floor finishes can be seen as well such as wood parquet (left) and ceramic tiles (right).

The café uses plywood flooring and ceramic tiles which are fairly non slippery so it is mostly suitable for strollers, wheelchairs, etc. (Fig. 3). The café is of one flat level which prevents any difficulty of getting from one level to the other (for wheelchairs, etc.). The main entrance does not use any doors during the time the café is open, providing ease of accessibility (Fig. 2 (left)). The door to the outdoor space is manual (push/pull) which can limit accessibility, such as for women carrying their infant in a stroller (as shown in Fig. 1 (center)).

4.2 Evaluating the case study using the rating system

Based on these observations the rating shown in Table 2 was provided.

Table 2: Rating for Segafredo Café.

Criteria	Points (out of 5)
Spatial layout	
The spaces are not male dominated and intimidating	3
The spaces make women feel safe through transparency and visual connections	4
The spaces provide adequate lighting	5
The spaces provide natural surveillance	5
Circulation	
The circulation routes provide sufficient width to allow all genders to use them	4
There are separate circulation routes for women only spaces	N/A
Provision of amenities	
Washrooms for women are provided and of adequate size (no queues forming)	N/A
Breastfeeding rooms and changing rooms are provided	N/A
Praying areas for women are provided	N/A
Furniture and finishings	
The space uses non slippery flooring that is suitable for strollers, wheelchairs, etc.	4
The space provides infant chairs as an option	1
The furniture provided accommodates different body types and sizes	4
The space uses automated doors for more accessibility	3
The space provides ramps with the right slopes for strollers, wheelchairs, etc.	N/A
Total (out of 45)	33

N/A = not applicable.

The rating given was 33 out of 45, which is 73.3%, indicating good performance. Segafredo Café performed adequately overall in terms of spatial layout, circulation, finishings, and furniture, with the main criteria that were lacking were in the provision of facilities that cater towards specific groups, such as provision of an infant chair for women with infants, and provision of automated doors for women carrying strollers and women using wheelchairs.

As the time allocated for this research was limited, there was not enough time to collect feedback from female participants about the rating system. As ideas for further development, the rating system could further be developed from workshops that can be carried out where participation is encouraged from the female users on how to improve the guidelines. The participants can give feedback and voice their needs regarding the four parameters of the rating system, allowing the constant revision and development of the rating system. The rating system could also be supported by a questionnaire with scalable answers to obtain the female visitors' feedback. The statements would be in the form of questions regarding the

female user's experience, such as: Do you feel safe in the space? Is the furniture comfortable? Can your child's needs be easily accommodated?

5 CONCLUSION

Designing spaces that are inclusive and welcome to everyone should be a priority for architects and interior designers, especially towards demographic groups that have historically been ignored in the design process. Therefore, it is important to make sure that spaces are gender inclusive and make women feel welcome, comfortable, and having their needs met. A rating system consisting of four main parameters – spatial layout, circulation, provision of amenities, and furniture and finishings – was created as a tool to evaluated the inclusivity of commercial spaces for women in Bahrain. The rating system was applied to a local case study, Segafredo Café located in Riffa, Bahrain, in which the café scored 73.3%, indicating a good performance. The café was suitable overall in terms of spatial layout, with the main criteria that were lacking were in the provision of facilities that cater towards specific minority groups.

The research contributes to the body of literature regarding inclusivity for women in Bahrain and the Middle East, which is currently lacking and insufficient. Moreover, the creation of the rating system can help keep design professionals more informed about how their decisions impact women's use of the space, as well as encouraging women to participate in the rating system's development to further accommodate their needs.

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REFERENCES

[1] Imrie, R. & Hall, P., *Inclusive Design: Designing and Developing Accessible Environments*, Taylor and Francis: London, 2004.
[2] Spain, D., Women's rights and gendered spaces in 1970s Boston. *Frontiers: A Journal of Women Studies*, **32**(1), pp. 152–178, 2011.
[3] Spain, D., Gender and urban space. *Annual Review of Sociology*, **40**(1), pp. 581–598, 2014.
[4] Rahmani, L. & Messaoudene, M., Gendered and gender-neutral character of public places in Algeria. *Quaestiones Geographicae*, **40**(2), pp. 119–137, 2021.
[5] Spain, D., *Gendered Spaces*, University of North Carolina Press: NC, 1992.
[6] Hanson, J., The inclusive city: Delivering a more accessible urban environment through inclusive design. Presented at *RICS Cobra International Construction Conference: Responding to Change*, UK, 2004.
[7] Ramster, G., Greed, C. & Bichard, J.A., How inclusion can exclude: The case of public toilet provision for women. *Built Environment*, **44**(1), pp. 52–76, 2018.
[8] URBACT, Gender sensitive public space? Placemaking and spatial justice through the perspective of gender. https://urbact.eu/gender-sensitive-public-space-placemaking-and-spatial-justice-through-perspective-gender. Accessed on: 2 Jun. 2022.
[9] Swain, J., French, S., Barnes, C. & Thomas, C., *Disabling Barriers: Enabling Environments*, SAGE Publications: London, 2004.
[10] Potter, N., *What is a Designer*, Hyphen Press: London, 2002.

[11] Feminism in India, Women in public spaces: When gender is ignored while shaping cities. https://feminisminindia.com/2020/11/12/women-in-public-spaces-street-safety/. Accessed on: 2 Jun. 2022.
[12] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/Vg873KLBjRpQKbQ3A. Accessed on: 2 Jun. 2022.
[13] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/F2trLLjZPRi2Yz6x5. Accessed on: 2 Jun. 2022.
[14] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/JsgUJgzKqecFHmDC6. Accessed on: 2 Jun. 2022.
[15] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/Kuos63gNk4TVMXsa9. Accessed on: 2 Jun. 2022.
[16] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/LD7yXDxv2obXFnXTA. Accessed on: 2 Jun. 2022.
[17] Google Maps, Segafredo Zanetti Espresso. https://goo.gl/maps/TEGjztyzgoaTawJr6. Accessed on: 2 Jun. 2022.
[18] Google Maps. Segafredo Zanetti Espresso. https://goo.gl/maps/ThLxArEcvKNzXpKX8. Accessed on: 2 Jun. 2022.

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SMART MATERIALS AND ADAPTIVE BUILDING ENVELOPES AS AN APPROACH FOR REDUCING ENERGY CONSUMPTION IN EGYPT: A LITERATURE REVIEW

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ABSTRACT

In the last 10 years, a quantum leap occurred in Egypt in the field of architecture that led to the consumption of large quantities of energy during implementation. It was noted that most of the buildings were designed to mimic the technological development in the architectural formations' trends globally, without considering the environmental impacts in Egypt or the resources availability in the future to operate these buildings. Therefore, the research was built on the premise that the operating cost will be prohibitively expensive, which requires offering solutions that can be applied during or after implementation in the operating stage that can help to control the cost of the building life cycle. The initial hypothesis of the research was about finding a solution for energy consumption percentages and controlling cost throughout using different types of smart materials that being used in the building envelope and its effect on the building performance, especially public utility buildings. Other reasons for this research are to help in protecting natural resources and achieve more adaptation for the building envelope throughout performing alternative materials characteristics, and to achieve Egypt Vision 2030 (SDS) and the global vision SDGs.

Keywords: material characteristics, energy consumption, operating cost, Egypt vision, building envelope, performance, numerical simulation.

1 INTRODUCTION

Architectural design is moving toward the integration of building technology and equipment in response to the desire for building envelope designs that can reduce energy demand. The ultimate goal is to produce a "smart envelope" that can undertake new jobs in addition to performing better than a typical building shell. Numerous studies show that the construction sector has the ability to increase energy efficiency at a reasonable cost.

The envelope deals with the building parameters including the skeleton of the building, construction materials Characteristics, cladding options design and the relation between all this parameters and energy efficiency for building performance.

This operation systems account for 70% to 80% of the total energy consumed in buildings. Energy costs roughly account for about 30% to 40% of the total operating cost of a typical building. Improving energy efficiency in buildings is essential to achieving the goals set by the Egyptian government in the Sustainable Development Strategy (SDS), Agenda (Egypt Vision 2030) and the international vision in sustainable development goals (SDGs) [1] as it reduces the energy consumption and consequently the emission of greenhouse gases without jeopardizing human comfort [2].

Taking into consideration the economic status in Egypt in recent years, especially the investment sector will demonstrate the enormous increase in construction sector, which would create massive energy consumption that was never in proportion with the growth in generated power in Egypt.

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1.1 Sustainability international vision

1.1.1 Egypt Vision 2030 (Sustainable Development Strategy (SDS))

The Sustainable Development Strategy (SDS): Egypt Vision 2030, which draws inspiration from ancient Egyptian culture and connects the present to the future, is a step toward equitable development. Consequently, supporting economic and social fairness as well as revitalising Egypt's position as a regional leader would lead to prosperity.

SDS stands for a strategy for achieving competitive advantage in order to fulfil Egyptians' hopes and desires for a respectable and decent existence [1].

The SDS was created through a participatory strategic planning methodology, in which a variety of civil society groups, national and international development partners, and government organisations worked together to establish all-encompassing goals for the nation's pillars and sectors [1].

The SDS has adopted the sustainable development principle as a general framework for enhancing welfare and quality of life while taking into account the rights of future generations to a prosperous existence. This involves dealing with the three main dimensions of the economic, social, and environmental spheres. The main strategic visions of SDS pillars are: the economic dimension, the environmental dimension, the social dimension) (Fig. 1). the research will focus on one dimension and will take tow pillars of this dimension [1].

- The economic dimension:

  A) Energy pillar (improving the efficiency of building sector, applying environmental standards and accurate measurements).
  B) Knowledge, innovation, scientific research (increase environmental sustainability sub-index of the global innovation (rank) from 65 to 30).

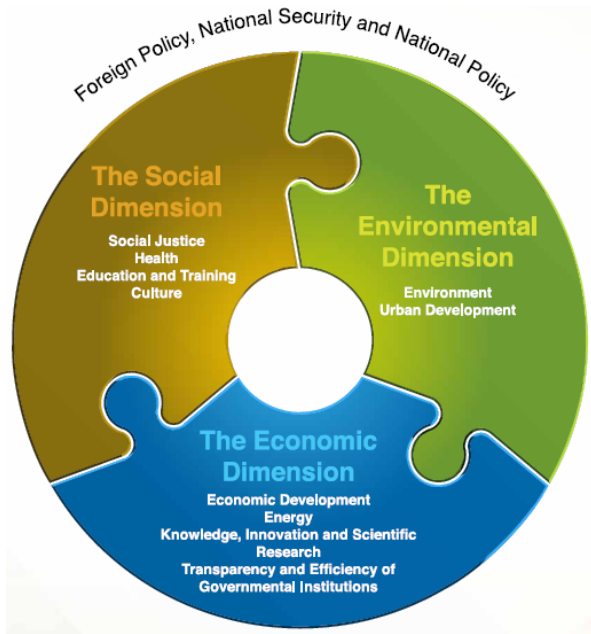


Figure 1: Strategic visions of SDS [1].

1.1.2 The international vision in sustainable development goals (SDGs)
The sustainable development goals are a global call to action to end poverty, protect the earth's environment and climate, and ensure that people everywhere can enjoy peace and prosperity. These are the goals the UN is working on in Egypt (Fig. 2) [2].

Figure 2: The international vision in sustainable development goals [2].

The research will focus on the "7. Affordable and Clean Energy" goal in SDGs and link it with the SDS 2030 [2].

1.2 Problem statement

Design and construct a building that fulfil all operational requirements of the users and reduce energy consumption through building life cycle is an unprecedented challenge for our times. Most of the buildings in Egypt are designed to mimic the technological development in the architectural formations' trends globally, without considering the environmental impacts in Egypt.

New approaches have appeared in the field of materials and its characteristics such as performative materials and smart materials that could enhance building performance but not applied yet in with wider scale. Researchers, practitioners are faced with enormous challenges due to the need to take account of various dynamic processes around us such as: global climate change and growing occupant needs and comfort expectations.

1.3 Research hypothesis

Smart materials and adaptive building envelope is the gate for reducing energy consumption through building life cycle. Cost is an important factor for the success of architectural design, and by studying it, the design can be converted into a real building.

1.4 Scope

This research will focus on the relation between material type especially smart materials, building envelope response in the scope of energy consumption and how these factors will affect Egypt Vision 2030 (Sustainable Development Strategy (SDS)) economically.

2 PERFORMANCE AND MATERIAL

2.1 High performance building "from traditional to integrated"

Prior to the industrial revolution, building efforts were often directed throughout design and construction by a single architect a method called the master builder model. The master builder alone bore full responsibility for the design and construction of the building, including any details required [2]. With the means of supplying heat, light, water, and other building services frequently being tightly integrated into the architectural parts, this paradigm lent itself to a building being built as a single system [3].

Lately, integrated design process appeared to design building with high performance strategy, buildings that used this integrated design approach frequently have high performance and sustainability.

This transition wasn't random or intentional; rather, it was brought on by the expanding variety of tools and technologies employed in design and construction as well as the complexity of those tools and technologies [4].

2.2 High performance building characteristics

Concern over the use of energy and water resources has made high-performance buildings particularly apparent, but it also encompasses other, larger issues like indoor environmental and air quality, material utilisation, well-thought-out development and design, and so on.

There are currently statutory rules and/or voluntary certification programmes for green buildings in several nations across the world [3].

Many different terms are used in the discussion of building design and performance. Green is one of those words that can have many meanings, depending on the circumstances. Like green, sustainable is primarily focused on environmental impact. High-performance is the preferred term used in this text when discussing buildings. Minimizing impact on the environment is one component of a high-performance building, but the building must also simultaneously provide a healthy, comfortable indoor environment [3].

2.2.1 Life cycle assessment (LCA) of high-performance building

A building designated as high-performance is one that is successful, over its full life cycle, in the following areas:

- Minimizing natural resource consumption
- Optimizing the quality of the indoor environment
- Reducing unwanted effects on the construction site
- Improving how well the new construction project is integrated into the general built and urban environment.
- Minimizing the discharge of solid waste and liquid effluents.

In addition to addressing the potential for energy use, a high-performance building makes sure that its function (occupant productivity) is not affected [3].

2.3 Materials in high performance buildings (energy efficiency approach)

> Materials are physical. they are available to our senses through perception.
> Materials are seen, touched, even smelled and tasted.
>
> Tim Ingold, Social Anthropologist

The materials form the cornerstone of building construction, and current technologies are anticipated to benefit them [4]. Traditionally, material has been a follower of form; it mostly alters the final appearance of the architectural product but does not participate in the initial stages of design. In fact, it appears that the design process is controlled by the hierarchical sequence "form–structure–material" when viewed from the perspective of building systems [5]. Both professionally and academically, the study of material structure and its function in creative design has grown in importance.

The study of and understanding of material function in design has grown to be a significant component of the field of architecture and one of its research topics.

The methods for modifying representations of material structures are also included in these study fields [4], and to raise awareness of developments in material applications (Fig. 3).

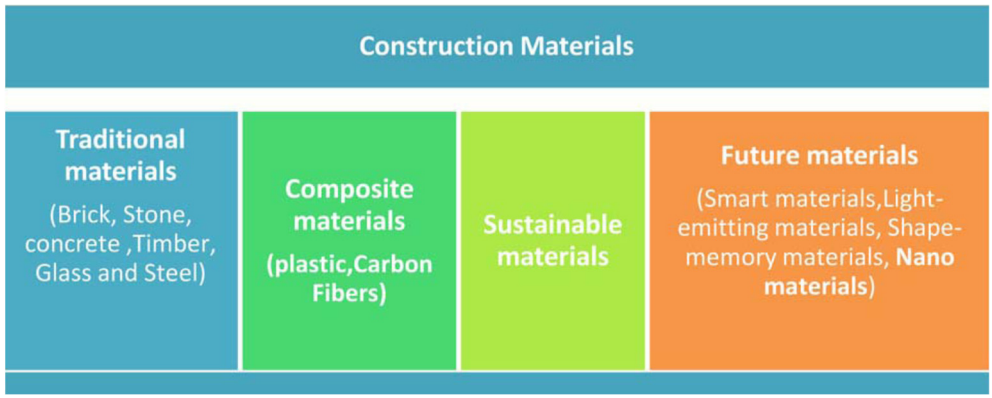


Figure 3: Material types [4].

In the rapidly changing building sector, planners, architects, engineers and builders are looking for new materials to adopt in future constructions that benefits like energy efficiency [4]. The development of new smart materials in the field of architecture, which we can control and adapt in terms of their thickness, pattern density, stiffness, colour, flexibility, and translucency, emphasises this design philosophy and offers us new possibilities and potentials that have an impact on our thinking, as shown in Fig. 4 [4].

2.4 Traditional building materials classification

Depending on the classification goal, building materials can be categorised in a variety of ways. Construction's primary classification systems primarily focus on composition, technical characteristics, environmental sustainability, and the function provided by a building system or size scale (Table 1). Building materials are often categorised into the following primary classes based on their composition [4].

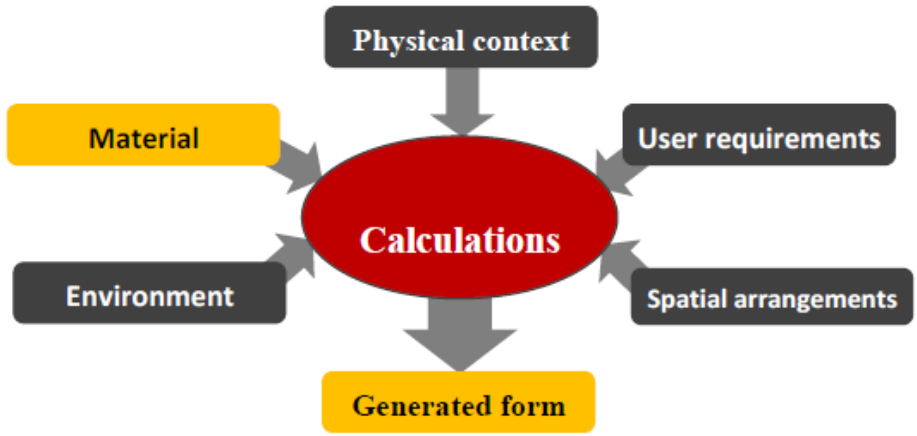


Figure 4: The development materials [4].

Table 1: Traditional building material classification [4].

Category subcategory	Category subcategory
Composition	• Metallic materials, ceramic materials, polymeric materials, composite materials.
Technical properties	• Mechanical, thermal, electrical, optical, acoustic, magnetic, chemical, radioactive.
Sustainability	• Renewability, recycled content, embodied energy, absence of toxic substances, compo stability, degradability, recyclability, reusability, durability, easy maintenance, global warming potential, ozone depletion potential, acidification potential.
Function	• Materials for use in the construction industry include but are not limited to the following: Binders and aggregates for mortars and concrete, structural components, load-bearing elements, windows, thermal and acoustic materials, water- and vapor-proofing materials, paints, primers, solvents, and adhesives.

2.5 Advanced materials

Advanced materials are those that are specifically created to have new or improved technical properties (structural or functional) or environmental features in comparison to materials that are typically used to carry out the same functions. These materials can be both new and derived from modifications of existing materials [6]. The use of cutting-edge materials in construction is significantly improving buildings' energy and environmental performance throughout their lifespans and bringing about significant improvements in every aspect of the construction process, from planning to execution.

In fact, advanced materials are a critical enabling technology for many other technologies, and they play a significant role in enabling advanced/high-value manufacturing and tackling society's major socioeconomic concerns, such as climate change and increased resource efficiency [6].

2.5.1 Smart materials definition

"Smart materials" are similar to living beings in that they have the ability to perform both sensing, actuating functions and are capable of adapting to changes in the environment. By utilizing these materials, a complicated part in a system consisting of individual structural, sensing and actuating components can now exist in a single component.

In the field of building, smart materials and their manufacturing techniques may provide a variety of advantages, including [5]:

- Superior toughness, ductility, and strength.
- Increased service life and durability.
- Enhanced resistance to chemicals, corrosion, abrasion, and fatigue.
- Lifecycle and initial cost efficiencies.
- A better ability to react to catastrophic situations like fires and natural catastrophes.
- Ease of production and use or installation.
- Compatibility with the surroundings and aesthetics.
- The capacity for structural control, self-healing, and diagnosis.

These advantages show how the design and construction sector can think outside of the box, The following is a previous advantages classification of smart materials Fig. 5 [6].

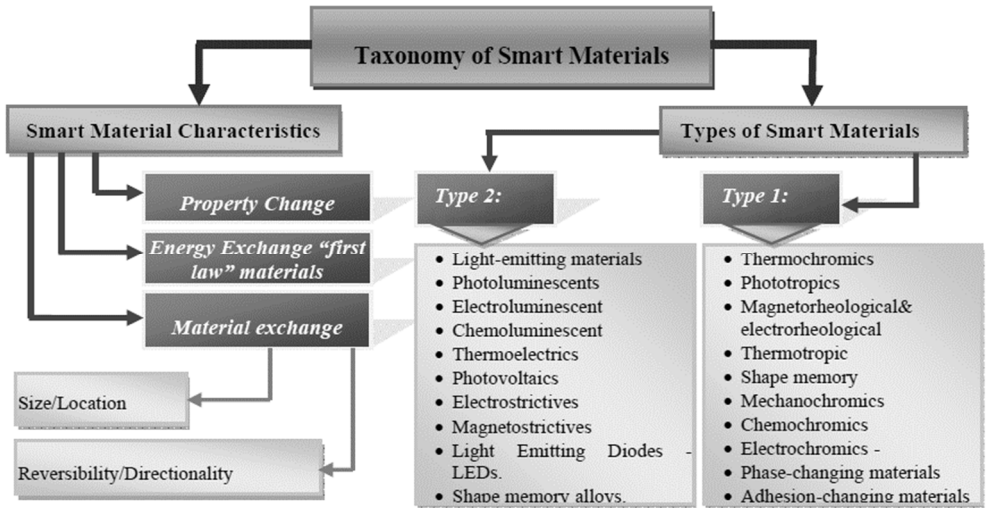


Figure 5: Classification (taxonomy) of smart materials [6].

2.5.2 Smart material characteristics

1. Property change: In reaction to a change in the environment, these materials experience a change in one or more of their properties, including chemical, thermal, mechanical, magnetic, optical, or electrical [7].
2. Energy exchange: These substances, which are also referred to as "first law" materials, convert an input energy into an output energy in line with the first law of thermodynamics. The potential usefulness of the energy is substantially bigger even

though smart materials like photovoltaics and thermoelectric typically convert energy at much lower rates than do conventional energy conversion technologies [7].

3. Material exchange:
   - Size/location.
   - Reversibility/directionality.

2.5.3 Types of smart materials

Smart materials and systems could be divided into two classes:

Type 1 Materials undergo changes in one or more of their properties (chemical, electrical, magnetic, mechanical, or thermal) in direct response to a change in external stimuli in the surrounding environment. The energy input to a material affects the internal energy of the material by altering the material's microstructure (Table 2) [8].

Type 2 Smart materials transform energy from one form to another. The energy input to a material changes the energy state of the material composition but does not alter the material, it stays the same, but the energy undergoes a change Applications of smart materials in architecture (Table 3) [5].

Table 2: Materials undergo changes in one or more of their properties [8].

Type 1	
Thermochromics	An input of thermal energy changes the material's color
Phototropic	Materials that change color when exposed to light.
Magnetorheological and electrorheological	The application of a magnetic field (or for electro-rheological – an electrical field) causes a change in micro-structural orientation, resulting in a change in viscosity of the fluid.
Thermotropic	An input of thermal energy (or radiation for a phototropic, electricity for electro tropic and soon) to the material alters its microstructure through a phase change. In a different phase, most materials demonstrate different properties, including conductivity, transmissivity, volumetric expansion, and solubility.
Shape memory	An input of thermal energy (which can also be produced through resistance to an electrical current) alters the microstructure through a crystalline phase change. This change enables multiple shapes in relationship to the environmental stimulus.
Mechano-chromic	Materials that change color due to imposed stresses and/or deformations
Chemo-chromic	Materials that change color when exposed to specific chemical environments.
Electro-chromic	Materials that change color when a voltage is applied. Related technologies include liquid crystals and suspended particle devices that change color or transparencies when electrically activated.
Phase-changing materials	Use chemical bonds to store and release heat.
Adhesion-changing materials	Change the attraction forces of adsorption or absorption of atoms or molecules when exposed to light or electrical field.

Table 3: Smart materials transform energy from one form to another [5].

Type 2	
Light-emitting materials	That convert an input energy to an output of radiation energy in the visible spectrum.
Piezoelectric	(An input of elastic energy – strain produces an electrical current. Most piezoelectric are bi-directional in that the inputs can be switched and an applied electrical current will produce a deformation – strain).
Thermoelectric	An input of electrical current creates a temperature differential on opposite sides of the material.
Photovoltaics	An input of radiation energy from the visible spectrum produces an electrical current.
Electro-strictive	The application of a current produces' elastic energy – strain which deforms the shape of the material.
Magneto-strictive	The application of a magnetic field produces elastic energy – strain which deforms the shape of the material.

2.5.4 Application on smart materials

By focusing on phenomena rather than the physical artefact, the use of modern technologies based on smart materials has the potential to dramatically increase the sustainability of buildings [9]. By responding locally, discreetly, and only, when necessary, energy consumption may be decreased. Then a wider variety of designs for both new construction and building retrofit may take use of many of the benefits provided by these technologies [10]. Either molecular structure or microstructure governs a material's qualities (Fig. 6).

3 ADAPTIVE BUILDING ENVELOPE

Adaptive building envelopes are referred to as a building skin that has the ability to change its characteristics and regulate a variety of aspects. These adjustments are made in response to changing climatic loads or the interior environment, which can improve comfort for the occupants [11].

The modification might be made in a number of ways, for as by relocating parts, adding airflows, or changing a material's chemical composition.

It's not a novel concept to modify a building's skin's performance, which depends on both the intended inside climatic conditions and the exterior climate. The concept of adaptable building skin is linked to biomimicry, intelligent structures, and intelligent materials [11].

3.1 Characteristics and properties of sustainable high-performance facades

High-performance facades could be described as the external building envelopes that consume the minimum amount of energy to retain a convenient indoor environmental quality, which improves the well-being and productivity of people inside the building. The properties of these building envelope include: (1) permit penetrating of natural light inside the building spaces; (2) stop undesired solar heat from penetrating the interior spaces; (3) stop heat transference through enhanced insulation; (4) blocking air and moisture from penetrating through the building; and (5) permitting natural ventilation to enhance the internal room temperature and air quality. These properties depend mostly on climate, in addition to the

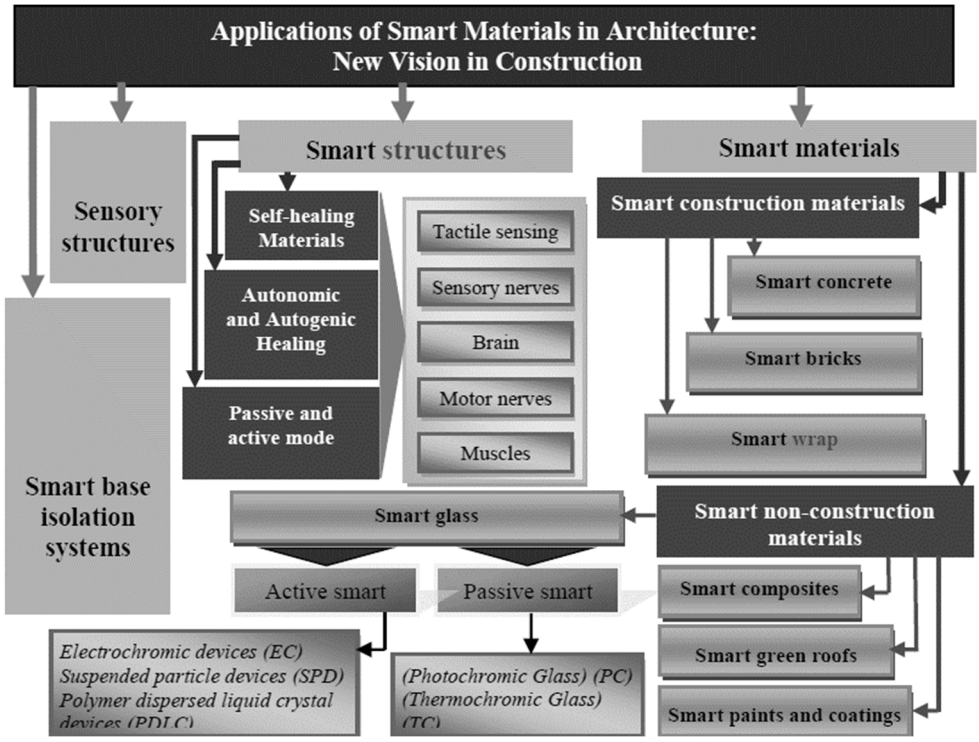


Figure 6: Application of smart materials [10].

building's operations, residence basis, orientation, and energy burden of equipment, moreover, the façade type [12].

3.2 Smart materials and adaptive envelope applications in the field of energy consumption reduction

Table 4 shows case studies with (high performance, smart material, adaptive envelope), it shows the reduction in energy consumption [10], [12].

4 DISCUSSION AND CONCLUSION

Smart materials will have an increasing range of applications and the underlying sciences in world. It must be maintained at a standard which helps achieve technological objectives which mean that smart materials and system must solve engineering problems and provide an opportunity for creating new products and could have an important role in sustainability architecture. From the data collected in this research regarding material function/system, this will speed the development of new materials for the use in different applications.

Smart materials and systems are able to sense and respond to the environment around them, they have the potential to improve existing technology and add new functionality to products.

In addition, smart materials are considered as "building envelope of the future" that combines various wall functions into a single product.

Table 4: Comparison table for case studies [10], [12].

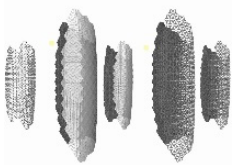
Building	Envelope design	Envelope type	Energy reduction
The Barcelona Media-ICT building		Smart materials in adaptive building envelope	ETFE material, the building generates 20% less in energy consumption. ETFE: (Ethylene Tetrafluoroethylene) Polymer This decreases the solar factor (SF) by four times, from 0.45, as accepted by the building Code, to 0.10.
Al Bahar Towers by Aedas	 	Responsive facade system in adaptive building envelope	Decrease solar gain by more than 50% and decreases the usage of air conditioning. In addition, its capability to filter and reduce the direct solar gain to a maximum of 400 W per linear meter.
Qatar National Convention Center, by Jorge Chapa		Energy exchanging smart material	The building will feature 3,700 square meters of solar panels, which will provide around 12% of the building's total power. The previous systems are using type 2 energy exchanging smart materials.
Geotube, Dubai by Faulders Studio		Smart material	Photovoltaic panels consider the application of smart material/system type 2.

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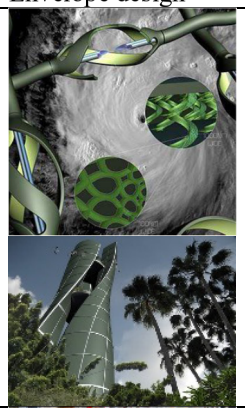
Table 4: Continued.

Building	Envelope design	Envelope type	Energy reduction
Nano vent skin demonstrated in Concept Tower, Agustin Otaegui		Nano – smart material and skin	Nano vent skin (NVS) is a building skin that uses organic photovoltaics to capture sun and micro-wind turbines to capture wind. NVS is just acting as a merger of different means and approaches into energy absorption and transformation, which will never happen in nature.
Shanghai World Expo 2010, UK Pavilion by Thomas Heatherwick		Recyclable material	Steel and timber composite structure pierced by 60,000 fiber optic filaments, 20mm square in section, which pass through aluminum sleeves.

It became evident that the use of smart materials in the adaptive envelopes for buildings contributed to lowering the amount of energy used in the operating stage based on the aforementioned and prior analyses of buildings as well as the analysis of the types of smart materials and their use and relation to the performance of the building.

Additionally, based on the international vision (SDGs) (Affordable and Clean Energy goal) and Egypt's 2030 Vision (Sustainable Development Strategy (SDS)) and according to the Egyptian Ministry of Electricity and Energy 2022 study, buildings account for 40% of Egypt's yearly energy consumption. To address this urgent economic need, the researcher argues for the use of smart materials in building envelopes, particularly in public buildings. This will be done in future studies. The amount of energy savings will be calculated based on geographical location, the type of smart material utilised, and the material's life cycle assistance.

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REFERENCES

[1] Egypt Vision 2030 report. https://mped.gov.eg/EgyptVision?id=59&lang=e. Accessed on: 15 Sep. 2022.
[2] How the UN is supporting The Sustainable Development Goals in Egypt. https://egypt.un.org/en/sdgs. Accessed on: 15 Sep. 2022.
[3] Hall, M.R., *Materials for Energy Efficiency and Thermal Comfort in Buildings*, Woodhead Publishing, 2010.
[4] Addington, D.M. & Schodek, D.L., *Smart Materials and New Technologies for the Architecture and Design Professions*, London, 2015.
[5] Casini, M., *Smart Buildings, Advanced Materials and Nanotechnology to Improve Energy-Efficiency and Environmental Performance*, Elsevier Ltd, 2016.
[6] Mohammed, T.B., Application of smart materials in the interior design of smart houses. *Civil and Environmental Research*, **7**(2), 2015.
[7] Youssef, A.S., Smart materials innovative technologies in architecture towards innovative design paradigm. *Alternative and Renewable Energy Quest, AREQ 2017*, Spain, February, 2017.
[8] Gharabaghi, M. & Naghdi, A., Identifying smart materials and applying them in residential spaces in cold climate case study: City of Hamadan. *International Research Journal of Applied and Basic Sciences*, **9**(1), pp. 51–62, 2014.
[9] Hussain, A. & Kamal, M.A., Energy efficient sustainable building materials: An overview. *Engineering Analysis*, **6**(2), pp. 20–25, 2017. DOI: 10.4028/www.scientific.net/KEM.650.38.
[10] Butt, A.A., de Vries, S.B., Loonen, R.C.G.M., Hensen, J.L.M., Stuiver, N., van den Ham, J.E.J. & Erich, B.S.J.F., Investigating the energy saving potential of thermochromic coatings on building envelopes, 2021.
[11] Aggour, M. & Soliman, O., Smart materials: Toward a new architecture. 2015.
[12] Shahin, H.S., Adaptive building envelopes of multi-story buildings as an example of high-performance building skins. Alexandria Engineering Journal, 58, pp. 345–352, 2019. www.elsevier.com/locate/aej.

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WILL BIOPHILIC DESIGN BECOME ANOTHER CHECKLIST?

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ABSTRACT

The dominance of an environmental solution – in green building certifications – over the social and the economic led many scholars and practitioners to consider Biophilic Design (BD) as an innovative way of designing. Deriving from "biophilia", the term suggests reconciling the innate human desire of nature with our built environment. In a sense, there is a deliberate attempt to merge the philosophy of BD with pre-existing standardised certification systems, confirming compliance with established norms and standards; however, the certification of healthy buildings should primarily be determined not only by the technical characteristics of materials, rules and procedures, but also by the quality of life considering occupants' emotional, intellectual and physical well-being. The literature review in this research paper included recent scientific publications about Biophilic Design, sustainability and green building certifications. To narrow down the selection criteria of references, researches that are of empirical nature and contextualised in Dubai were selected; moreover, the qualitative investigation in this research was enhanced by a pedagogical application in which students enrolled in the course "Building Systems and Codes" at the American University in the Emirates proposed ways to integrate Biophilic Design at buildings and urban scales. The findings of this research demonstrate that the concept of Biophilic Design is being considered in green building certifications like LEED, WELL, Fitwel, Living Building Challenge Certification and BREEAM. While the term "biophilic" was recently coined, its principles and tools were already previously implemented in architecture, as example in the famous Falling Water by Frank Lloyd Wright. Interpretation of Biophilic Design in formalisation and standardisation remains challenging to achieve human-centred design. The quest to measure Biophilic Design firstly, in construction costs and, secondly, humans' well-being adds another layer of complexity. The critical approach of "biophilia" may be where the real value is.

Keywords: Biophilic Design, green building certifications, sustainability, design education, Dubai.

1 INTRODUCTION

Biophilic Design (from the word Biophilia as an innate human desire for nature) is an innovative way of design. Biophilia is not a separate characteristic of a person, but is an internal orientation that determines a person's way of thinking and acting. In a sense, it is a "relative" of green design – the philosophy of designing physical objects that are harmoniously integrated into the environment and do not harm it. The aim of Biophilic Design (BD) is to bring the elements of nature into the room. It is believed that over the course of many years of life in their natural habitat, a person has formed certain genetically encoded reactions to light, weather, terrain, plants and animals [1] and now part of our emotional, intellectual and physical well-being depends on the ability to interact with these elements. Recently, BD has come to be seen as an element to better merge urban planning with architecture.

People spend most of their lives indoors and continue to worry exclusively about the outside world [2]. Climate change, environmental pollution, garbage disposal, deforestation and the disappearance of various species of wild animals have remained at the top of the discussed news for decades. The quality of life inside the premises seems to worry the mass consciousness much less. Many scientific studies reason qualitatively and quantitatively regarding well-being problems and solutions where living environments may positively intervene. One will find numerous spam messages, real estate ads, advertising brochures from

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construction companies, discussions about apartment design, the right selection of furniture, streaming product promotion without social agenda.

In regulated societies, certification systems for buildings and structures are understood as measures aimed at confirming the compliance of construction work, materials and equipment with established norms and standards. Adding new regulations to those existing, even with the best of intentions, may complicate, the process of construction work. The certification of healthy buildings should primarily be determined not only by the technical characteristics of materials, rules and procedures (which, of course, need to be developed), but also whether they adhere to the rules of the specific certificate and fulfil their structural and functional role [3].

Accordingly, we are not talking about another unification and standardisation of construction, but about the formation of a movement for healthy buildings, in which rating and ranking are far from the first place, but serve as auxiliary elements for monitoring the quality of construction work and will facilitate the decrease in the depression and perceived stress levels of its residents especially in view of the COVID-19 pandemic [4]. In a document-centric management culture, Awadh [5] points out the dominance of an environmental solution over social and economic. If successful innovations in construction become possible only in developed countries, it is not because they have a larger money supply, but because success may be an inverse function of the formalisation and bureaucratisation of efforts [6]. The emphasis of the certification system for healthy buildings on human requests is not a figure of speech, but a postulate, an axiom that determines further steps in the interpretation and implementation of requirements set along the lines of a specific standard manifested in world approved systems, namely LEED, WELL, Fitwel, Living Building Challenge Certification and BREEAM.

2 LEED

Some consider Leadership in Energy and Environmental Design (LEED) certification system as the world's most successful, thoughtful and widely accepted assessment of healthy buildings. It is not surprising that the authors dwell in detail on the basic principles and norms, describe the mechanisms for obtaining and maintaining the status of a leader in energy and environmental design. The certification covers nine areas: (1) sustainable sites – maintaining the integration and complexity of building solutions; (2) location and transport – location and transport infrastructure; (3) education and priority; (4) water efficiency – efficiency of water consumption; (5) energy and atmosphere – energy consumption and atmospheric parameters; (6) material and resources – consumption of materials and resources; (7) indoor environmental quality; (8) innovation – design innovation; and (9) regional priority – regional characteristics and priorities. Mind, little has been mentioned on the integration of the building into nature. The main aim is to "support and improve human health, well-being and productivity by providing and incorporating elements of nature in the indoor environment". Therefore, the focus is on the human being and one's role within the structural system of the built environment.

Developed in 1994 by the U.S. Green Building Council (USGBC) under the scientific leadership of Robert Watson, LEED certification has transformed from a linear set of standards and procedures into a comprehensive certification system that takes into account the individual developer profile, sociocultural environment and government priorities [7]. The interdisciplinary nature of certification requires the involvement of specialists in urban and transport planners, architecture, electrical and water supply, urban design, biology and botany, but most importantly, social researchers who connect professionals and users of premises, allow for trust and productive relationships [8].

3 WELL BUILDING STANDARD

A new WELL Building Standard has appeared in the international certification system, which assesses the "health" of buildings. The WELL Building Standard was developed in 2015 by a group of scientists who identified the main factors affecting the health of workers. Over the course of seven years of scientific and medical research, scientists have developed a technical standard and put into it the requirements that a modern "healthy" office building must meet. According to the WHO definition, health is not only the absence of diseases, but also the state of physical, social and mental well-being of people. During their work, they spend less time outdoors, and more time indoors. The state of health and labour productivity depend on the quality of the internal environment, engineering systems and working conditions. The results of research by scientists indicate that the cause of respiratory, cardiovascular diseases, allergic reactions and obesity is the poor quality of the internal office space [9]. WELL focuses on the design, operations and behaviours within the allocated space bearing in mind the potential of optimisation to advance human health and well-being. Therefore, the main focus is also the health and wellness of final residents with immense attention paid to the space itself incorporating nature, pattern and the aspect of interaction with nature.

Although the WELL Building Standard is relatively new, it is closely intertwined with the existing ones. For buildings certified to BREEAM or LEED green building standards, it is much easier to implement the WELL Building Standard. WELL certification for existing buildings will increase the market value of the property, the building's operational efficiency and marketing advantages over competitors [10]. For new construction projects, WELL Building Standard, together with LEED/BREEAM certification, will attract foreign tenants, improve the quality of design solutions, reduce operating costs and increase corporate and social responsibility.

4 FITWEL

Fitwel is another healthy building standard. It is, like WELL, focused on human health. In estimate BREEAM and WELL have about 30% overlap, while WELL and Fitwel have about 60%. Nevertheless, Fitwel is very different from its closest "competitor" and has every chance of becoming more popular. According to statistical data, in 2018 as much as 600 projects attempted to be certified through Fitwel in 20 countries. First, Fitwel is a much more democratic standard. To obtain the WELL certificate, one is required to carry out a large number of instrumental tests: water, air, and others. At the same time, WELL has technical requirements that are overestimated in some positions, and even impracticable in others. For example, in terms of ventilation the standards range from one country to another, and the same is for building materials. Fitwel does not provide any measurements at all, and, in general, is determined by the results of the on-site inspections [10]. Yes, Fitwel has testing requirements such as air quality. But it is enough to carry out tests on them and simply demonstrate their results to tenants. Accordingly, since there are no costs for all kinds of measurements, the price for a Fitwel certificate is significantly lower. For example, if WELL costs about $100,000, Fitwel would cost about $15,000–$20,000.

This, however, does not mean that getting a Fitwel certificate is very easy: the entry threshold is very high – you need to score at least 90 points. It should be borne in mind that Fitwel excludes the influence of the human factor, which plays an important role in obtaining the WELL certificate. All measurements in WELL are carried out by a real specialist and a lot depends on how carefully specialists check, how you interact with them.

Another fundamental difference between Fitwel and WELL is that Fitwel focuses on design, engineering, creating a certain type of living environment. Therefore, the results of the "healthy environment" certification are more noticeable to the layman in facilities built

according to the Fitwel standard. Such buildings are designed to stimulate a person to move, lead a healthy lifestyle. For example, this may include a central location and unusual staircase designs to encourage employees to walk up the stairs instead of using the elevators.

5 LIVING BUILDING CHALLENGE CERTIFICATION

Leading companies around the world are incorporating a regenerative design structure into their projects to create spaces based on Living Building Challenge (LBC) principles. There are seven of these principles, which are usually compared to the seven petals of a flower. The symbol of the LBC is a flower, metaphorically, a flower that gives more to the world than it takes. The Living Building Challenge is a certification that identifies the most advanced resilience measures – laying the foundation for design, construction and symbiotic relationships between people and all aspects of the built environment [11]. This is one of the strictest performance standards in the industry as every project requires clean energy, sustainable materials, water and waste management.

Every aspect of the Living Building Challenge is performance based, so each building must be measured for 12 consecutive months after completion before being certified. The seven petals are place, water, energy, health and happiness, materials, equity and beauty. While each of these petals hints at the need to care for the environment, there is not a single hint of unity with nature.

6 BREAM

Another example of international green certification is the BREEAM (BRE Environmental Assessment Method) used around the world. As part of BREEAM, BRE Global maintains a Sustainable Development Council representing the largest shareholders in the construction industry. BRE Global trains independent licensed BREEAM assessors worldwide, controlled by UKAS in accordance with the ISO9001 quality system [12].

The BREEAM rating system is popular not only in the UK. Outside its borders, more than 110,000 buildings have been certified to date, and about half a million buildings have to go through this process. Exceeding legal requirements seems to be the main reason for the popularity of the BREEAM standard in the construction market. Developers and designers are interested in enhancing the performance of buildings that BREEAM provides.

Investors and urban planning authorities are interested in reducing time and financial costs. Real estate agencies provide themselves with additional advertising. The customer, tenant or potential buyer is confident in the high quality of the final product. Another feature of the assessment system is the methodology for awarding points in several sections related to various aspects of life safety, environmental impact and comfort. The scores are multiplied by weights reflecting the relevance of the aspect at the development site, then summed up and converted into a resulting score. This technique allows the BREEAM system to be adapted to different regions without sacrificing efficiency. Some of these sections are energy, water, materials, recycling and use of land.

The overall score is the rating given: satisfactory, good, very good and excellent. The BREEAM system serves as an example of a successful concept that effectively implements the protection of the environment from human activity by meeting the interests of all market participants.

7 CRITIQUE

Biophilic Design is considered young as it has not been implemented in modern building projects for a long period of time. Utilising the example developed by Frank Lloyd Wright in his Falling Water house, one can admit that the latter seemingly adheres to all standards

aforementioned. The house above the waterfall includes several blocks – this is the main house of the owners, a house for servants and a guest house, as well as a garage. Interestingly, in all of these blocks, Wright sought to organically combine artificial and natural elements [13]. For example, in some places the window panes are not inserted into the frames, but directly into the masonry. In addition, in some rooms, the architect deliberately made low ceilings, hinting to the owners that they need to spend more time outdoors and not in the building.

From the external point of view, the building is a set of parallelepipeds, arranged with each other, having fairly recognisable proportions. The lower level has an orientation to three cardinal points. On the second floor there are the bedrooms and the study of the owner of the house, each room has its own spacious terrace overlooking the stream and waterfall. On the upper third level, there is a gallery bedroom, which also has access to its own outdoor terrace. Whether a given solution meets the criteria for organic architecture must be investigated and proven separately, having previously understood the basic concepts [14]. All vertical elements of the building are made of durable local stone, its individual fragments protrude from the masonry, demonstrating their natural texture. The horizontal parts of the house are made of reinforced concrete using monolithic technology. Wright played with the protruding part of the natural rock, making it one of the central elements of the interior of the house.

Despite the evident fit to the explanation of Biophilic Design, there still has been little research done on the topic where scholars considered the long-term issues within the field. Other concerns relate to the upfront and maintenance costs of projects to implement costly BD principles. This may be due to the lack of research discussed above, as there is little information available on payback times for investors. Another concern may be the cost of the required technology; however, this should eventually come down as the concept becomes more prevalent.

People spend most of their lives indoors, so it is time for social researchers to pay attention to such an important area of human existence, to think about the most important living conditions and the characteristics of green buildings and the overall interconnectedness with nature [2]. These include, first, possible environmental threats (radiation, chemical, physical and biological) [1], [15]; second, building design (ventilation, pressure boosting, filtration, lighting, acoustics); third, social factors (location and safety); fourth, behavioural factors (biography of residents, employment and health care); fifth, the quality of the adjoining territory (chemical composition, walking accessibility, noisiness and landscaping) [16]; sixth, architectural design (availability of fitness centres, food courts, BD and open space for daylight); seventh, maintenance (repair work, cleaning and pest control). It is necessary to move on to the study of the private, intimate – housing that can make us happier, or can slowly annihilate any aspirations for success, independence and well-being.

8 APPLYING BIOPHILIC DESIGN IN A PEDAGOGICAL FRAMEWORK

One of the program learning outcomes in the Interior Design (ID) program at the American University in the Emirates is to appraise sustainability in industry practices; however, currently, environmentally friendly design framework is limited to technical criteria measured in different assessments across several courses in the program. To bridge the gap between a quantifiable, technical approach in understanding environmental sustainability and the human innate desire to connect with nature, BD has been introduced in the pedagogical framework of the ID program, specifically, in the course Building Systems and Codes [17]. The assessment was introduced in the form of a research paper through several phases following a workshop introducing students about BD. Participating students analysed secondary data from published research papers then considered their outcomes for possible

implementation in the Emirate of Dubai, where ID students are currently pursuing their studies. Building Systems and Codes was offered in Spring semester (from January to May 2022) and a synthesis of the results pertaining to BD assessment is demonstrated in the following sections.

One of the workshop participants noted that while biophilic patterns exist outside the campus building, the indoors of the American University in the Emirates Campus may benefit using a "five-zone strategy" [18]: departmental units, project units, creative groups, imaginative groups, and centre of gravity. This would entail reconfiguration of spaces and major redesign of layout and aesthetic components. While the suggested strategy may not be fully implemented, the proposal implies a practical aspect to BD in indoor university campuses, boosting innovation and sustainability.

Figure 1: Campus of the American University in the Emirates. *(Source: Sanjana Garag.)*

Linking Building Systems and Codes with BD, an observation of another participant depicts that "Habitable spaces, other than a kitchen, shall be not less than 7 ft (2134 mm) in any plan dimension. Kitchens shall have a clear passageway of not less than 3 ft (914 mm) between counter fronts and appliances or counter fronts and walls". denoting that existing international building codes consider minimum dimensions of space and equity especially in residential buildings [19]. Biophilic Design does not impose minimum dimensions of spaces, revealing the fact that the former is complementary to approved existing building standards and not mandatory from authorities having jurisdiction.

World Expo Dubai 2020 was one of the main events spanning urban and architectural levels. Although it was temporary, the life cycle was conceived in way that District 2020 will be a city following the infrastructure originally built for the world expo. The exhibition aimed at demonstrating exemplary projects in sustainability. In fact, one of the three main districts in the world expo was named Sustainability district in which the Sustainability Pavilion is one of the pavilions that would not be dismantled after the event. A participant in the workshop commented "Involving sun oriented power as the essential wellspring of energy rather than petroleum derivatives, particularly in the UAE, would be a huge advance towards sustainability. Dealing with the vegetation in the region by growing a variety of trees and plants would likewise help by enhancing the environment nearby and having a more secure, better climate. All this would improve the district regarding a decent climate, yet combining it with Biophilic Design would improve it for individuals of the local area" [20].

A student highlighted that Biophilic Design would have definitely been a limelight during the COVID-19 pandemic when people were forced to work from home [21]. Studies showed that productivity actually increased by working from home rather than working in office. While adhering to biophilic principles in a workplace may result in additional costs, a happy and more productive environment would be considered in the return on investment. "Both offices and schools are spaces where occupants may face stress and fatigue due to long hours of work and mental engagement where focus is necessary otherwise productivity suffers. Since productivity is a very important aspect of both offices and schools that defines their effectivity, it is necessary to try and maximise it. The benefit of using Biophilic Design is that while maximising productivity it also serves to benefit the psychological well-being of the occupants which may not always be a priority to employers who mainly seek productivity even at the detriment of the employees".

In Dzhambov et al. [22], the study considered different sources of greenery like houseplants, green view, garden, and neighbourhood greenery. There is a direct path linking presence of houseplants to reducing depression. Houseplants are also directly related to the feeling of being away (at home) that is in its turn a mediator linked to reducing depression and anxiety. Greenery in the neighbourhood is directly linked to restorative quality that is directly connected to the feeling of social support, a mediator that is inversely proportional to depression and anxiety. Although the survey sample in the aforementioned study was not in Dubai, the quantitative results was used by a student in the workshop to propose the use of social media to promote greenery in the form of gifts offered either to the users themselves or to the others depending on the occasion. A second proposal was to implement greener neighbourhoods in Dubai similar to Al Barari and Damac Hills areas.

9 CONCLUSION

This research gave an overlook over five prominent green building certifications where Biophilic Design (BD) is being directly or indirectly integrated namely LEED, WELL, Fitwel, Living Building Challenge Certification and BREEAM. The process of standardising and commercialising BD still lingers among practitioners and researchers. As a critique, the research clarified that the principles of BD were previously implemented even though the term itself was not used. In academia, specifically, in design education, the topic is being thoroughly thought of as it is human-centred; furthermore, BD is being interwoven with sustainability in course assessments as demonstrated by the author through samples of outcomes in a workshop he conducted to Interior Design students at the American University in the Emirates in the course Building Systems and Codes. The outcomes showed some opportunities where BD may be applied in the city of Dubai as the local city where they are pursuing their degrees. It is worth mentioning that green building certification mostly used

in Dubai is LEED. If BD were to be standardized using a top-down approach in Dubai, it is only an evident possibility that BD would be integrated in LEED. Studies showed that BD has positive impact on occupants' psychological health indoors regardless the use of the considered building: office, residential, commercial, or others. Design considerations directly related to occupants' mental health must be considered as a priority over financial benefits. If BD were to be adapted as a checklist in standardisation, many disciplines must be involved in the process including urban designers, architects, engineers, psychologists, philosophers, social scientists, and artists.

REFERENCES

[1] Lupton, E. & Lipps, A., *The Senses: Design Beyond Vision. Cooper Hewitt*, Smithsonian Design Museum and Princeton Architectural Press, 2018.

[2] Browning, W., Ryan, C. & Clancy, J., *14 Patterns of Biophilic Design*, Terrapin Bright Green LLC, 2014.

[3] Cecconi, F., Moretti, N., Mannino, A. & Dejaco, M., Sustainability certification of construction products through BIM. *IOP Conference Series: Earth and Environmental Science*, **296**(1), 012054, 2019.

[4] Kharaba, Z., Al-Azzam, S., Alhusban, A. & Nseir, K., A look behind the scenes: COVID-19 impact on depression and perceived stress of UAE population. *Middle East Current Psychiatry*, pp. 28–35, 2021.

[5] Awadh, O., Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis. *Journal of Building Engineering*, **11**, 2017.

[6] Makram, A. & Abou Ouf, T., Biomimetic and Biophilic Design as an approach to innovative sustainable architectural design. *AR-UP 2019: 3rd International Conference of Architecture and Urban Planning,* Department Faculty of Engineering, Ain Shams University, Cairo, 2019.

[7] Kaluarachchi, Y. & Jones, K., Promoting low-carbon home adaptations and behavioral change in the older community. *Architectural Engineering and Design Management*, **10**, pp. 1–2, 2013.

[8] Africa, J., Heerwagen, J., Loftness, V. & Ryan Balagtas, C., Biophilic Design and climate change: Performance parameters for health. *Frontiers in Built Environment*, **5**(28), 2019.

[9] IWBI, *The WELL Multifamily Residential Pilot Addenda*, International WELL Building Institute: New York, 2020.

[10] Bernardi, E., Carlucci, S., Cornaro, C.A. & Bohne, R., An analysis of the most adopted rating systems for assessing the environmental impact of buildings. *Sustainability*, **9**, 2017.

[11] Pishdad-Bozorgi, P. & Shah, A.P., Case study of a Living Building Challenge project. *55th Annual International Conference Proceedings*, Associated Schools of Construction, 2019.

[12] BREEAM, *BREEAM Communities. Technical Manual SD202–1.2:2012*. BRE Global Limited: Watford, UK, 2012.

[13] Richardson, M., Dobson, J., Abson, D.J., Lumber, R., Hunt, A., Young, R. & Moorhouse, B., Applying the pathways to nature connectedness at a societal scale: A leverage points perspective. *Ecosystems and People,* **16**(1), 2020.

[14] Sharifi, M. & Sabernejad, J., Investigation of biophilic architecture patterns and prioritizing them in design performance in order to realize sustainable development goals. *European Online Journal of Natural and Social Sciences: Proceedings,* **5**(3), 2016.

[15] Lumber, R., Richardson, M. & Sheffield, D., Beyond knowing nature: Contact, emotion, compassion, meaning, and beauty are pathways to nature connection. *PLoS One*, **12**, 2017.
[16] Brown, M., *FutuREstorative: Working Towards a New Sustainability*, RIBA Publishing: London, 2016.
[17] Wijesooriya, N., Brambilla, A. & Markauskaite, L., Developing a pedagogical model for Biophilic Design: An integrative conjecture mapping and action research approach. *WIT Transactions on the Built Environment,* vol. 195, WIT Press: Southampton and Boston, 2020.
[18] Abdelaal, M.S., Biophilic campus: An emerging planning approach for a sustainable innovation-conducive university. *Journal of Cleaner Production,* **215**, pp. 1445–1456, 2019.
[19] Fezi, B.A., Health engaged architecture in the context of COVID-19. *Journal of Green Building*, **15**(2), pp. 185–212, 2020.
[20] Wijesooriya, N. & Brambilla, A., Bridging Biophilic Design and environmentally sustainable design: A critical review. *Journal of Cleaner Production*, **283**, 2021.
[21] Gillis, K. & Gatersleben, B., A review of psychological literature on the health and wellbeing benefits of Biophilic Design. *Buildings*, **5**(3), pp. 948–963, 2015.
[22] Dzhambov, A.M., Lercher, P., Browning, M.H., Stoyanov, D., Petrova, N., Novakov, S. & Dimitrova, D.D., Does greenery experienced indoors and outdoors provide an escape and support mental health during the COVID-19 quarantine? *Environmental Research*, **196**, 2021.

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CLASSIFICATION OF PHOTOVOLTAICS IN BUILDINGS (BAPV AND BIPV): ILLUSTRATED WITH ZERO-ENERGY HOUSES

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ABSTRACT

Zero-energy buildings are one of the most effective decarbonization strategies for cities. They are highly efficient buildings that can generate enough energy to meet their demand using renewables. Photovoltaics (PV) is a cost-effective way of generating renewable energy in buildings. Additionally, PV modules can be more than generation systems and be an essential part of the buildings, contributing to their appearance, thermal performance, and daylight harvesting. New policies and regulations around the world encourage the use of PV and bring more flexibility for their integration in buildings. Therefore, it is fundamental for regulators, researchers, and building professionals, to have a comprehensive PV in buildings categorization. As a response, the objective of this work was to develop a classification for building attached photovoltaics (BAPV) and building integrated photovoltaics (BIPV). The classifications resulted from an extensive literature review that helped to identify relevant aspects, criteria, and gaps in previous categorizations. It considers the application type, location, opacity, accessibility from the inside, and heat dissipation (a missing parameter in prior works). After summarizing the existing categories, describing the findings, and explaining the proposed classifications, the authors illustrated them using zero-energy houses.

Keywords: photovoltaics, photovoltaics ventilation, BAPV, BIPV, zero-energy buildings, solar decathlon.

1 INTRODUCTION

One of the most effective strategies to make our cities greener is implementing zero-energy buildings (ZEB) [1]. These buildings can generate enough energy to cover their demand using renewable energy sources [2]. Most ZEBs around the world generate their energy from photovoltaic (PV) systems, a solution for energy generation that has been used in buildings since the 1970s [3]. However, PV modules can be more than just energy generators attached to buildings. They can also be multifunctional elements seamlessly integrated into the architectural design. The Wohnanlage Richter residential complex in Munich, Germany designed in 1982 with polycrystalline cells on its curtain walls, is considered the first case of PVs integrated into the building design [4]. More recently, policies and regulations around the world encourage using PV in buildings and facilitate their integration. Consequently, it is fundamental to have a comprehensive classification of PV in buildings that considers all the relevant aspects of their applications and integration.

The most common differentiation between PV installation in buildings is related to their integration or not the building. A building attached photovoltaic (BAPV) is a solution in which the PV modules are superimposed or attached over already built building surfaces, having electricity production as the only or primary objective. On the other hand, building integrated photovoltaic (BIPV) technologies comprise multifunctional elements that, in addition to electricity generation, replace conventional building materials and construction elements on the roofs, walls, glazing, and sun control systems [5]–[7]. Several categorizations have been published in the last decade, utilizing different criteria and primarily focused on BIPV solutions. In most of them, the common criterion is the solution location (roof, wall, and exterior elements). In addition, BIPV systems have been categorized

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by the type of BIPV products [8], [9]; by the type of systems and the way of integration into the building envelope [10]; and by their accessibility or not from the building interior, as the BIPV categories given in the standard EN 50583 [11]. Experts from the IEA Photovoltaic Power Systems Programme (PVPS) have valuably contributed to PV in buildings and recently published a BIPV categorization [12]. Additionally, researchers from the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) also conducted an influential categorization of BIPV categories has also been done by Frontini et al. [13].

Even though previous classifications consider several aspects of PV and their relationship with buildings, there is a need for a more comprehensive classification. Most of the classification efforts have been focused on the BIPV, and some essential aspects of the PV performance, such as the modules ventilation, are not part of the more complete categorizations. Therefore, the objective of this work was to develop a comprehensive classification for both BAPV and BIPV, considering the used criteria, strengths, and gaps in previous categorizations. The parameters of the proposed classification include the application type, location, opacity, accessibility from the inside, and ventilation. The relevance of ventilation in the performance of PV has been documented in the literature. However, even the most detailed classifications do not include ventilation or heat dissipation.

The remainder of this article is organized as follows: Section 2 explains the methodology, Section 3 summarizes the literature review, Section 4 describes the proposed classification, Section 5 illustrates the classification using zero-energy houses, and finally, Section 6 presents the conclusions.

2 METHODOLOGY

To provide a comprehensive categorization of PV in buildings that can be useful for regulators, researchers, manufacturers, and building professionals, the authors first established the research's topics and limits. Then, they carried out an in-depth literature review, analyzing the results and extracting the most relevant findings, as shown in Fig. 1.

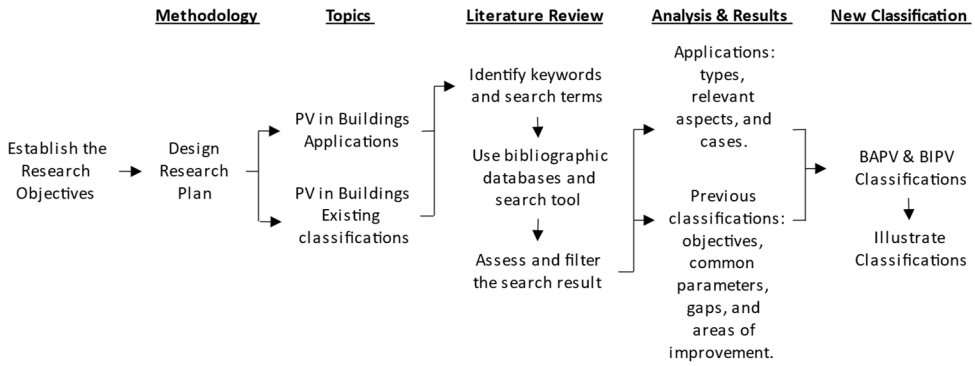


Figure 1: Methodology chart.

The studied topics and the resulting classifications included both BAPV and BIPV solutions. The literature review phase included the search for different ways to install PV in buildings and the existing PV in buildings categorizations. This phase had three parts, the keywords selections, the search in bibliographic databases, and the assessment and filtering of the results. These results were the base for analyzing types and relevant aspects of PV in

building applications, as well as the strengths and opportunities for improvement of previous classifications. Finally, the authors developed the BAPV and BIPV classifications, applying the lessons learned from the literature.

3 LITERATURE REVIEW OF EXISTING CLASSIFICATIONS

Various classifications can be found in literature, which vary on purpose (e.g., market, research) or criteria (e.g., technology, spatial relationship with the buildings). This section introduces BAPV and BIPV solutions and summarizes the literature review of the most completed classification systems of PVs in buildings based on three criteria: electrotechnical, construction, and architectural design (aesthetics or visuals).

Conventional photovoltaics superimposed or attached over already built building surfaces with the only o primary purpose of energy generation are referred to as building applied photovoltaic (BAPV) or building attached photovoltaics [14]–[16]. While photovoltaics that, in addition to the energy generation, also serve as a building envelope element or an external component, meaning they are part of the building architectural design, are referred to as BIPV [12], [13].

Overall, BIPVs have more advantages than BAPVs. They can benefit in different areas such as energy conservation, material use, building function and aesthetics. However, in some cases, the tightness of the building envelope can be affected by the BIPV elements. Additionally, the durability of the BIPV system can be reduced since they do not perform in an autonomous mode but in coupled mode with other building envelope materials might lead to less longevity for this system [17].

3.1 Classifications based on construction and electrotechnical criteria

Moving further into more detailed based classifications, one of the most comprehensive classifications of PVs in buildings is proposed by the International Energy Agency (IEA) [12] as a part of their aim to help accelerate the penetration of BIPV products in the global market of renewables, giving them an equal playing field with BAPVs and other building envelope elements. These classification systems, created as a hierarchical classification approach based on a combination of two classification criteria, have five levels that go from the building to the PV cell scale, as Table 1 shows.

Table 1: IEA BIPV classification [12].

Criteria	Level	Parameters
Construction	I. Application	Integration, accessibility, and slope
	II. System	Location (roof, façade, external element)
Electrotechnical	III. Module	Transparency, planarity, mechanical rigidity, size, thermal insulation, and customization
	IV. Component	Module component (front cover, encapsulant, solar cells, back cover, frame, and edge sealing
	V. Material	Type of material of the module components

I. Application

The application level is based on the first international standard for BIPV, the ISO EN 50583 [11]. This standard sets health and safety protection requirements for PVs in buildings as both electrotechnical and construction components. This classification is presented as a

reference for the requirements of PV that contain glass (considered as construction components in buildings), where the requirements vary based on the type of PV mounting system. Depending on where the PVs are integrated into the building; whether they are accessible or not; and whether they are sloped or not, there can be five mounting categories according to EN 50583 [11]:

- Category A: Slopped, roof-integrated, not accessible from within the buildings.
- Category B: Slopped, roof-integrated, accessible from within the buildings.
- Category C: Non-sloped (vertically) mounted not accessible from within the building.
- Category D: Non-sloped (vertically) mounted accessible from within the building.
- Category E: Externally integrated, accessible, or not from within the buildings.

II. System

The BIPV systems as a building envelope element have three groups: roof, façade, and external integrated devices. Each of them matched the EN 50583 application categories. For example, the roofs match categories A and B, the façades to C and D, and the external integrated devices to E. The groups can be further subdivided, as indicated below [12].

- Façade: rainscreen façade, double skin façade, curtain wall, window, masonry wall.
- Roof: discontinuous roofing, continuous roofing, atrium/skylight.
- External integrated device: parapet, balustrade, canopy, solar shading.

III. Module

The modules classification follows the below criteria [12]:

- Transparency: opaque, translucent, semi-translucent, transparent, or semi-transparent.
- Planarity: flat or curved.
- Mechanical rigidity: flexible or rigid.
- Size: large, shingle (slate or tile), or regular.
- Thermal insulation: insulated or non-insulated.
- Standardization: standard or customized.

IV. Component

Typical PV modules have many components, such as interconnected solar cells encapsulated by a polymer (encapsulant) and covered on the front by a protective layer (glass or a polymer sheet) and at the rear cover layer (glass, a polymer sheet, or singular construction material) [12]. Additionally, they have metallic wires/ribbons to conduct the electricity, which are connected to a junction box installed outside the module. Finally, the frame (usually aluminium) is an optional component that provides additional structural support and is instrumental in the module's mounting.

V. Material

The material of the PV modules component can be [12]:

- Front cover: low iron float glass or tempered glass, Polymeric front sheets.
- Encapsulant: poly (ethylene-co-vinyl acetate) (EVA), polyvinyl butyral (PVB), polyolefin (PO), ionomers; silicones (curing and non-curing systems).

- Active material/solar cells: crystalline silicon; mono-crystalline Si or polycrystalline Si; thin-film solar cells: CdTe, CIGS, CIS, a-SI, organic molecules, perovskites.
- Back cover: glass panes, construction material panels, polymer materials.
- Frame and edge sealing: aluminium, polysiloxane, polyisobutylene.

There are two other less comprehensive classifications but equally relevant. The first of these classifications is focused on the market and product segmentation in BIPV [13]. This classification includes available systems, prices, applications, and technologies (crystalline, crystalline thin film, thin film, and custom-made). The second and more recent also related to the BIPV market [3], and based on the primary material used as cladding's outer layer, the transparency, and the level of thermal protection, distinguishes the following three typologies: Glazed semi-transparent BIPV solution (with thermal properties), Opaque glazed BIPV solution (without thermal protection), and Opaque no glazed BIPV solution (without thermal protection).

3.2 Classification based on visual criteria

Photovoltaics (PV) visual dimension, or how they are perceived, is crucial for the social acceptability of this technology [18], and although it is difficult to assess objectively, some classifications are based on this dimension. For example, Cronemberger et al. proposed a novel classification of PV in buildings based on their appearance. They named this classification "Architectural Design Approach". Its subcategories are invisible (out of the sight of the people), added (visible – performing a specific function), highlighted (to enhance the image of the building), and leading (preponderant – determining building image) [19].

More recently, an attempt has been made to assess it through a descriptive model based on visual parameters, describing PVs as visual objects, no matter the materials and technologies used [18]. The authors of this classification identified a set of visual performance objectives and translated them into visual and technological requirements. This classification aims to facilitate dialogue among different stakeholders, offering an objective comparison. The classification has three scales: coarse (building envelope application and systems), medium (PV modules and framing system), and fine (PV module components and materials). To each of the three scales mentioned previously, they applied three visual terms pattern, patch, and matrix, as Table 2 shows. Finally, the assessment of all these visual terms can be qualitative or quantitative. Qualitative assessments refer to a colour as red and a size as small. In contrast, quantitative assessments refer to the colour in terms of RGB and the size in terms of cm.

3.3 PV in buildings: heat dissipation

The operating temperature is critical in the photovoltaic conversion process, affecting the modules' efficiency and power output. That is even more crucial in PV in buildings due to the lack of proper cooling from the poorly ventilated rear side [20]. In addition to the ventilation, PV modules' heat dissipation can be improved using PV thermal hybrid systems (BAPV/T or BAPV/T) [21]. These systems can be water, air, or phase change material based.

Researchers in Ljubljana (Slovenia), a city with high temperatures in the warmest months ranging between 25°C and 30°C, conducted outdoor experimental research to evaluate the PV modules' ventilation effect on their temperature. They found that the temperature of the (unventilated) roof integrated PV modules was 21.8°C higher than those installed in an open rack with an instantaneous plane-of-array irradiance equal to 1000 W/m^2 [22].

Table 2: Visual classification – Pattern–patch–matrix model [11], [12], [18].

Visual scale	Terms	Description	Defined by
Coarse, medium, and, fine	Pattern	A specific arrangement of spatial elements, often referred to as spatial structure or patch structure.	Geometry; density
	Patch	Surface area that differs from its surroundings in nature or appearance.	Size; shape; position; border; colour; transparency; texture
	Matrix	Background cover type in a landscape, with an extensive cover and high connectivity (not all landscapes have a definable matrix).	Transparency; colour

A study investigated the effect that the variation between cell temperature and ambient temperature has on the performance of unventilated BIPV, and open rack mounted PV placed on a roof in the south of Greece [23]. This study resulted in an efficiency power coefficient of $-0.30\%°C^{-1}$ for the ventilated free-standing PVs and a coefficient of $-0.45\%°C^{-1}$ for the unventilated ones, reaching the conclusion that the difference between cell and ambient temperature decreases with increasing wind speed, and it highlights the critical role of adopting cooling measures in cases of high temperatures and unventilated modules.

A more recent experimental work in South Africa compared open-rack mounted PV modules with others installed on a sloped roof with gaps of 50 mm, 100 mm, and 150 mm. Its results reflect that in the cases, the heat dissipation factors of the open-racked modules were higher than those installed on the roof. For example, at a 15° tilt angle, the heat dissipation factor of the open-racked were 30.91 W/m^2K and 3.65 Ws/m^3K, and the ones on the roof were 24.41–24.58 W/m^2K and 3.67–5.10 Ws/m^3K [24].

3.4 Findings and reflexions

There are many categorizations of PV in buildings in the literature. Some are very detailed, going from the systems to the component levels. Likewise, research groups and international platforms are working actively to share the potentiality of PV in the built environment and have been involved in developing the different categorizations. However, the classification efforts have focused on BIPV modules and systems, leaving aside the BAPV possibilities, even those intended to reduce the negative effect on the building's appearance.

Also, heat dissipation, an essential aspect of PV performance, is not included in the current classifications. Similarly, PV thermal hybrid systems are not included in the more comprehensive categorizations. Furthermore, the authors found that it is crucial to have easily expandable classifications, to accommodate other concerns (aesthetics, for example) or to address different stakeholders' needs.

4 PROPOSED PV IN BUILDINGS CLASSIFICATION

The proposed classification system initially has five fields or categories: type, location, opacity, heat dissipation, and accessibility. Table 3 presents the potential subcategories for each of these fields. However, the classification is flexible enough to permit the addition of new fields and subcategories. For example, to have a complete description of the solution, including its visual and aesthetic values, a sixth and seventh field can be added to describe the architectural approach and the visual classification.

Table 3: Options for each classification field and their identification codes.

Field 1 **Type**	Field 2 **Location**	Field 3 **Opacity**	Field 4 **Heat dissipation**	Field 5 **Accessibility**
BA: **BA**PV **BI**: **BI**PV	**Rf**: **Ro**of **f**lat **Rt**: **R**oof **t**ilted **Rc**: **R**oof **c**urved **Wa**: **Wa**ll **Wc**: **C**urtain **w**all **Wd**: **D**ouble skin **Co**: **Co**ntinuous[2] **Es**: **E**xt. **s**hading **Eg**: **E**xt. **g**uardrail **Ep**: **E**xt. **p**orch **Ea**: **E**xt. **a**trium **Ef**: **E**xt. **f**loor **Ed**: **E**xt. **d**etached structure	**Op**: **Op**aque **Os**: **S**emi**O**paque[1] **Tr**: **Tr**anslucent	**Vf**: **V**entilation **F**ree (non-restricted) **Vr**: **V**entilation **r**estricted **Vn**: **V**entilation **N**o **Vi**: **V**entilation towards an **I**nterior space **Tw**: **T**hermal using **w**ater **Ta**: **T**hermal using **a**ir **Tp**: **T**hermal using **P**CM	**An**: **N**on-**a**ccessible from within the interior **Ai**: **Ac**cessible from within the interior **Ae**: **A**ccessible **e**xterior elements

[1] Refer to opaque modules separate to let pass the light, encapsulated in translucent cover and back panels.
[2] Refer to continuous architectural envelopes with non-discontinuities between walls and roofs.

This paper focused on the initial five fields. The first refers to the main categorization of PVs in buildings, BAPV and BIPV. The location is the second field, and its options are the roof, wall, continuous envelopes, and exterior elements. The continuous envelopes are contemporary architectural solutions in which there is a differentiation between the façades and the roof finishing; the envelope of the façade continues and covers the top of the building. Opacity level constitutes the third field and initially has three options, opaque, semi-opaque and translucent. In terms of the heat dissipation field, there are several potential options, going further than a simple distinction of ventilated or not. There is a distinction between free (non-restricted) ventilation, restricted ventilation, and ventilation towards the interior space – the latest for PVs that have direct contact with the inner space of the building. In the case of BAPV/T and BIPV/T, it must be specified if the system extracts the heat of the modules using water, air, or PCM. Lastly, the accessibility field adopts the accessibility options from the EN 50583 standard [11], where the "An" option will correspond to categories A (roof) and C (walls), "Ai" will correspond to categories B (roof) and D (walls), and the "Ae" to the category E.

The classification name follows the order of the fields, and each subcategory is identified by two letters. For example, **BA_RfOpVr_An** corresponds to PV modules **attached** to a flat **roof, opaque**, with **limited** (restricted) **ventilation,** and **non-accessible** from within the interior. The following sections will detail the potential options for each field, starting from the first filed distinction between BAPVs and BIPVs.

4.1 BAPV classification

As mentioned previously, the primary purpose of BAPV solutions is to generate electricity. Typically, they are installed on rooftops but can also be on walls.

BAPV categories are defined by the options selected in each field. The options for the second field, "Location", are roof and wall. In terms of opacity, considering that the primary purpose of generating energy, usually the modules are opaque. Moving on to the fourth field, generally, BAPVs are ventilated. However, this ventilation can be free (non-restricted) or

restricted. Lastly, in terms of accessibility, these systems are not accessible from within the interior space. Fig. 2 illustrates the potential classifications of BAPV solutions.

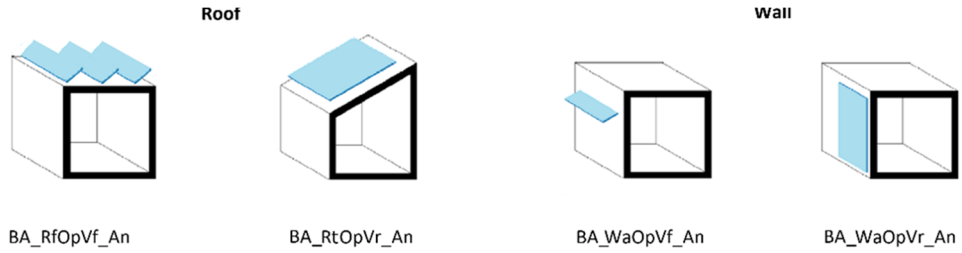


Figure 2: BAPV classification. The roof classifications apply to flat, tilted, and curved roofs.

PV modules in BAPV solutions can be installed, taking or not into account the appearance of the buildings. If the goal is to produce as much energy as possible, the appearance of the building is not relevant. Therefore, the modules are installed with the best possible azimuth and tilt angle without considering the installation's look and giving the modules free ventilation (Fig. 2(a) and (c)). However, if there is a secondary goal of reducing the impact of the building aesthetic, the PV modules are fitted close to the building envelope, parallel to the roof or walls surfaces (Fig. 2(b) and (d)).

4.2 BIPV classification

Starting from the second field, BIPVs can replace construction elements on roofs, walls, continuous envelopes, and building exterior elements. Therefore, there are more options for BIPV. In terms of opacity, unlike the BAPV, they can be either opaque, semi-opaque or translucent. In addition, they can be directly integrated into the building envelope, constituting ventilated façades or roofs, defining spaces, or bringing protection.

The fourth field, the level of ventilation, varies according to the location, mounting systems, and way of integration. All ventilation options apply to BAPVs: free ventilation, non-ventilated, restricted ventilation, and ventilation towards an interior space. Similarly, in terms of accessibility, all three options apply to BIPVs: non-accessible form within the interior, accessible form within the interior, and accessible exterior elements. Fig. 3 shows the potential classifications for BAPV.

5 CLASSIFICATIONS ILLUSTRATE USING ZERO-ENERGY BUILDINGS

The authors selected the zero-energy houses of the Solar Decathlon Middle East (SDME) 2018 to illustrate the application of the proposed classification. Solar Decathlon Middle East [25] is an international competition organized by Dubai Electricity and Water Authority (DEWA) under an agreement with the Dubai Supreme Council of Energy and the US Department of Energy. It challenges university students to design, build and operate sustainable zero-energy houses. This competition is created to demonstrate innovation in design and technology for potential zero-energy buildings (ZEBs) in the region [25]. In the 2018 edition, fifteen teams representing countries and universities reached the final phase of the competition. All the houses have PV on their roofs. In addition, some of them integrate PV elements as opaque and transparent components, as Figs 4 and 5 show.

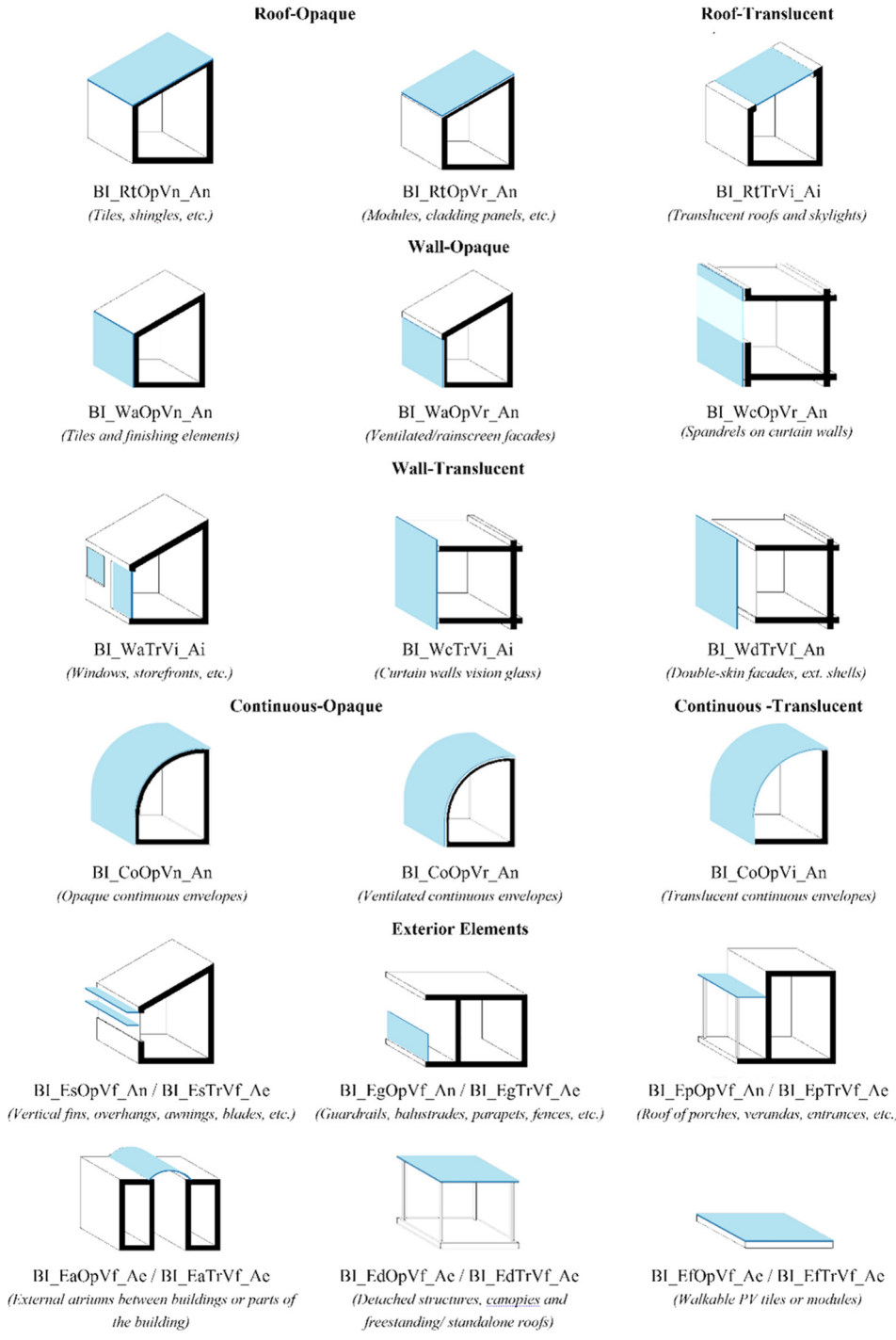


Figure 3: BIPV classification.

Figure 4: BIPV ventilated façade at BX house. *(Source: SDME Organization.)*

Figure 5: BIPV window at VT house's foyer. *(Source: SDME Organization.)*

The proposed classification facilitated the analysis of the houses under analysis in its five fields: type, location, opacity, heat dissipation, and accessibility accessible form within the interior or exterior. As expected, the preferred location for installing the PV elements was the roof, and as commented before, all the houses have PV on their roofs. That is justified by the high solar angles of the Middle Eastern countries. Additionally, in residential projects, the roof is less crowded than in commercial ones, bringing more space for the PV modules.

The houses presented tilted and flat roofs (typical roofs in arid climates), as Fig. 6 shows. Five teams placed the PVs parallel to the flat roof (AUD, BX, UOS, VT, and part of the HW), and four teams have the tilted PVs on the flat roof (AST, NCT, KS, and part of SUR). In the case of sloped roofs, all the PVs were placed parallel to the roof (UOW, USI, HW, TUE, part of the HW, and part of the SUR). Among them, two teams, HW and SUR, have part of the roof flat and another part sloped. The PVs are installed parallel to the flat and sloped roofs in these cases. AUR and NCT teams designed on-the-roof terraces shaded by PV canopies. Similarly, UOS roofed its balcony with PV modules, and BX, AST, and KSU shaded their courtyards with PV structures. In the case of BX, this PV shade is retractable.

Regarding roof integration, the teams developed several types of BAPV and BIPV solutions. Four teams chose BAPVs roof systems (AUD, NYU, UOS, and USI), eight teams chose BIPVs (AUR, BX, HW, KSU, NCT, SUR, TUE, UOW, and VT), while two teams had both BAPV and BIPV (AST and BU). In relation to the visual image and the architectural design approach of the PV roof systems, many teams (BU, SUR, UOS, and VT) opted for "invisible applications". They intentionally locate the PV modules out of people's sight [19]. Regarding façade integration, BX integrated strips of PV modules in the east, south, and west ventilated façades, and VT utilized PV glass in the window of their house foyer, as shown in Figs 5 and 6.

Most of the teams in the SDME 2018 edition decided to use opaque solutions. However, the BU and BX teams use semi-opaque PV modules as roofs of their courtyards. VT was the only team that used a transparent solution.

Heat dissipation is crucial for the optimum performance of the PV modules, and it is even more critical in the Middle East due to its high temperature and irradiance. Therefore, the PV modules in teams like AST and NYU that opted for standard BAPV solutions have non-restricted rear ventilation. Similarly, the modules as roofs for courtyards, terraces, and balconies might have even better ventilation, as in the cases of AUR, BX, BU, KSU, NCT, and UOS. However, the BAPV systems installed parallel to the roof and the BIPV on the

AST: BA_RfOpVf_An + BI_EpOpVf_Ae.

AUD: BA_RfOpVr_An.

AUR: BI_EdOpVf_Ae.

BU: BA_RfOpVr_An + BI_RfOsVf_Ae.

BX: BI_EaOsVf_Ae + BI_WaOpVr_An.

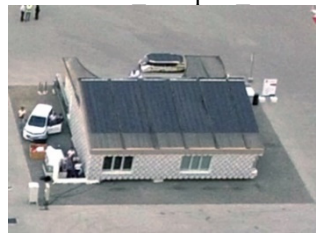
HW: BI_RtOpVr_An.

KSU: BI_EdOpVf_Ae.

NCT: BI_EdOpVf_Ae.

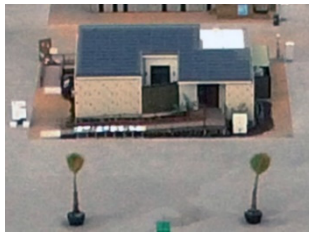
NYU: BA_RfOpVf_An.

SUR: BI_RtOpVr_An.



TUE: BI_RtOpTw_An.

UOS: BA_RfOpVr_An + BI_EpOpVf_Ae.



UOW: BI_RtOpTw_An.

USI: BA_RtOp_An.

VT: BI_RfOpVn_An + BI_WaTrVi_Ai.

Figure 6: Proposed classification implemented on the SDME 2018 houses. *(Source: SDME Organization.*

roof integrated as invisible applications or ventilated façades do not affect or enhance the houses' architecture but reduce the rear ventilation level. Therefore, they fall into the "restricted ventilation" category.

Two teams, UOW and TUE, designed a roof solution in which PV elements look like standard roof materials. For this, they adjusted their roof's shape and tilt angle to get optimum solar energy harvesting and seamless integration of their solar tiles and modules. In addition, these two teams used PV thermal hybrid solutions that ensure the correct heat dissipation and have as sub-product hot water that can be used for domestic needs.

Finally, accessibility from within the interior or the exterior is a criterion established by the EN 50583 standard [11]. That information is relevant for regulations due to its implications for structural, fire, and in-use safety. Only the PV glass of the VT house is accessible from within the interior of the house. Additionally, the PV canopies and porches can be accessible from the exterior of the houses.

6 CONCLUSION

Given the significance of comprehensively classifying photovoltaics in buildings, the author conducted an in-depth literature review of the different applications and the existing categorization of PV in buildings. Then, they proposed a unified and flexible classification that responds to diverse stakeholders' interests using the lesson learned in their research.

Excellent works on PV in buildings and several categorizations have been published in the last decade. However, most classifications focus on BIPV, not including BAPV solutions. In addition, the heat dissipation has not been addressed, and even the most detailed categorization does not include PV thermal hybrid solutions.

The proposed classification covers both BAPV and BIPV. The initial five fields are application type, location, opacity, ventilation, and accessibility. Once the classification was developed as implemented in the Solar Decathlon Middle East zero-energy houses. Finally, the findings from the classification's definition and its utilization were that:

- The proposal structure is flexible to be expanded to consider new fields and subcategories.
- The initial proposal is complete enough to address the BAPV and BIPV solutions found in the literature.
- Relevant aspects for the PV performance as the heat dissipation is taken into consideration, as well as PV thermal hybrid solutions such as BAPV/T and BIPV/T.
- Code and safety consideration as the EN 50583 standard.

The authors will keep working to improve their proposed classification and use it in the analysis of zero-energy buildings, hoping to contribute to the discussion of the harmonization of the PV in Buildings classifications.

ACKNOWLEDGEMENTS

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REFERENCES

[1] D'Agostino, D. & Mazzarella, L., What is a nearly zero energy building? Overview, implementation and comparison of definitions. *Journal of Building Engineering*, **21**, pp. 200–212, 2019.

[2] Torcellini, P., Pless, S., Deru, M. & Crawley, D., *Zero Energy Buildings: A Critical Look at the Definition*, National Renewable Energy Lab. (NREL), Golden, CO, 2006.
[3] Corti, P., Bonomo, P., Frontini, F., Mace, P. & Bosch, E., *Building Integrated Photovoltaics: A Practical Handbook for Solar Buildings' Stakeholders*, 2020.
[4] Chen, T., An, Y. & Heng, C.K., A review of building-integrated photovoltaics in Singapore: Status, barriers, and prospects. *Sustainability*, **14**(16), 10160, 2022. DOI: 10.3390/su141610160.
[5] Osseweijer, F.J.W., van den Hurk, L.B.P., Teunissen, E.J.H.M. & van Sark, W.G.J.H.M., A comparative review of building integrated photovoltaics ecosystems in selected European countries. *Renewable and Sustainable Energy Reviews*, **90**, pp. 1027–1040, 2018. DOI: 10.1016/j.rser.2018.03.001.
[6] Leslie, H., *Energy and the New Reality 2: Carbon-Free Energy Supply*, Earthscan: London, 2010.
[7] Berger, K. et al., International definitions of 'BIPV', Natural Resources Canada, 2018.
[8] Fedorova, A., Hrynyszyn, B.D. & Jelle, B.P., Building-integrated photovoltaics from products to system integration: A critical review. *IOP Conference Series: Materials Science and Engineering*, **960**(4), 42054, 2020.
[9] Jelle, B.P. & Breivik, C., State-of-the-art building integrated photovoltaics. *Energy Procedia*, **20**, pp. 68–77, 2012.
[10] Verberne, G. et al., BIPV products for façades and roofs: A market analysis. *29th European Photovoltaic Solar Energy Conference and Exhibition*, pp. 3630–3636, 2014.
[11] European Standard, EN 50583-1: 2016.
[12] Bonomo, P. et al., Categorization of BIPV applications. 2021. www.iea-pvps.org.
[13] Frontini, F., Bonomo, P. & Chatzipanagi, A., Building integrated photovoltaics. *Swiss BIPV Competence Centre, SUPSI*, 2015. http://repository.supsi.ch/7202/1/160112_BIPV_digitale.pdf.
[14] Ghosh, A., Potential of building integrated and attached/applied photovoltaic (BIPV/BAPV) for adaptive less energy-hungry building's skin: A comprehensive Review. *J Clean Prod*, **276**, 123343, 2020.
[15] Peng, C., Huang, Y. & Wu, Z., Building-integrated photovoltaics (BIPV) in architectural design in China. *Energy Build*, **43**(12), pp. 3592–3598, 2011.
[16] dos Santos, Í.P. & Rüther, R., The potential of building-integrated (BIPV) and building-applied photovoltaics (BAPV) in single-family, urban residences at low latitudes in Brazil. *Energy Build*, **50**, pp. 290–297, 2012.
[17] Celadyn, W. & Filipek, P., Investigation of the effective use of photovoltaic modules in architecture. *Buildings*, **10**(9), p. 145, 2020.
[18] Scognamiglio, A., A trans-disciplinary vocabulary for assessing the visual performance of BIPV. *Sustainability (Switzerland)*, **13**(10), 2021. DOI: 10.3390/su13105500.
[19] Cronemberger, J., Corpas, M.A., Cerón, I., Caamaño-Martín, E. & Sánchez, S.V., BIPV technology application: Highlighting advances, tendencies and solutions through Solar Decathlon Europe houses. *Energy Build*, **83**, pp. 44–56, 2014. DOI: 10.1016/j.enbuild.2014.03.079.
[20] Skoplaki, E., Boudouvis, A.G. & Palyvos, J.A., A simple correlation for the operating temperature of photovoltaic modules of arbitrary mounting. *Solar Energy Materials and Solar Cells*, **92**(11), pp. 1393–1402, 2008. DOI: 10.1016/j.solmat.2008.05.016.

[21] Yang, T. & Athienitis, A.K., A review of research and developments of building-integrated photovoltaic/thermal (BIPV/T) systems. *Renewable and Sustainable Energy Reviews*, **66**, pp. 886–912, 2016. DOI: 10.1016/j.rser.2016.07.011.
[22] Kurnik, J., Jankovec, M., Brecl, K. & Topic, M., Outdoor testing of PV module temperature and performance under different mounting and operational conditions. *Solar Energy Materials and Solar Cells*, **95**(1), pp. 373–376, 2011. DOI: 10.1016/j.solmat.2010.04.022.
[23] Kaldellis, J.K., Kapsali, M. & Kavadias, K.A., Temperature and wind speed impact on the efficiency of PV installations. Experience obtained from outdoor measurements in Greece. *Renew Energy*, **66**, pp. 612–624, 2014.
[24] Owen, M., Pretorius, J., Buitendag, B. & Nel, C., Heat dissipation factors for building-attached PV modules. https://ssrn.com/abstract=4119337.
[25] Solar Decathlon Middle East. https://www.solardecathlonme.com.

SECTION 2
ENVIRONMENTAL MANAGEMENT

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BUILDING SUSTAINABILITY ASSESSMENT BASED ON MATERIALS USED: CASE STUDIES IN LISBON, PORTUGAL

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ABSTRACT
Nowadays, sustainability is one of the main objectives of the world, also shared by the construction sector. However, despite the calls toward construction sustainability and its benefits, the project design decisions are often based only on the economic point of view, which is useful for the building cost but underestimates the materials' environmental impacts. The subject of this paper is the buildings' sustainability assessment, concerning the environmental impact of materials used, in two stages of the building life cycle: (i) building construction; and (ii) building occupation. In order to define the sustainability degree of the buildings, correspondence analysis as discriminant analysis was used to establish a numerical scale that allows comparing the buildings in relative terms. The buildings are scored and ranked through this scale. The Parque das Nações (Nation's Park) area, Lisbon, was chosen because it was designed to be an example of sustainable urban planning, with concerns for the preservation and conservation of resources. The methodology developed, which allows synthesizing in a single numerical value the buildings' sustainability, was tested in 30 buildings, with promising and intelligible results for non-professionals and professionals. In general, residential buildings reveal high sustainability than office buildings in the construction stage. In the occupation stage, both types of buildings reveal sustainability scores more similar.
Keywords: building sustainability, sustainable materials, barycentric discrimination, Parque das Nações.

1 INTRODUCTION

Several centuries ago, the human population was small, and the civilizations had few needs, which gave the illusion that natural resources were unlimited because the ability of nature to regenerate itself was much larger than the resources' usage rate.

Nowadays, there is awareness that natural resources are limited and that it is necessary to ensure a future for coming generations, through sustainable development [1]. In fact, at the world level, civil works and building construction consumes 60% of the raw materials extracted from the lithosphere [2]. From this volume, buildings represent 40%, or 24% of these global extractions [2]. This sector's intensive use of concrete, iron, metal alloys, plastics, and synthetic materials consumes large quantities of raw materials and energy, leading to depletion of resources and contributing to the increasing greenhouse effect [3]. The European Commission recognizes that "better construction and use of buildings in the EU would influence 42% of our final energy consumption, about 35% of our greenhouse gas emissions and more than 50% of all extracted materials; it could also help us save up to 30% water" [4].

To cope with this problem, in 1994 the Conseil International du Bâtiment (CIB) defined sustainable construction as "…creating and operating a healthy built environment based on resource efficiency and ecological design" [5]. Sustainable construction also concerns "the adoption of materials and products in buildings and construction that will require less use of natural resources and increase the reusability of such materials and products for the same or similar purpose, thereby reducing waste as well" [6]. Following the same line of thought, the


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Environmental Protection Agency (EPA) of the USA defines a green building as a building, which is designed, built operated, maintained, or reused with objectives to protect occupant's health, improve employee productivity, use wisely natural resources and reduce the environmental impacts [7].

So, sustainable construction must respect both the needs of the inhabitants and the natural resources of the Earth. It contributes significantly to environmental enhancement and quality of life improvement. Building sustainability also promotes the local economy and decreases energy consumption.

Furthermore, by choosing suitable materials, preferably durable and energy-efficient, the utilization costs decrease. This choice also contributes to increasing the buildings' life cycle, which can be, supported by maintenance procedures, extending furthermore until the building is eventually rehabilitated, avoiding the demolition waste.

However, despite the calls toward construction sustainability and its benefits, the project design decisions are often based only on the economic point of view, which is helpful for the building cost but underestimates the materials' environmental impacts.

Thus, the question arises of assessing the sustainability grade of buildings constructed in the last decades.

This paper seeks to achieve the quantification of a qualitative variable such as building sustainability, taking into account the materials that were applied. A methodology based on Correspondence Analysis as Discriminant Analysis, mathematically developed by Ribeiro [8] and Pereira et al. [9], was used to show the quantitative results for 30 buildings in Lisbon, following the research work of Barbosa [10], Ribeiro and Barbosa [11] and Barreto [12]. Thus, the aim is to obtain the sustainability grade of a particular building in relation to others with similar construction characteristics.

Another objective, more general, is consolidating the methodology to quantify the quality variability.

2 BRIEF LITERATURE REVIEW

Until recently, the only method to evaluate the sustainability of products was the life cycle assessment (LCA), which "seeks to quantify the environmental impacts over the infrastructure life cycle by identifying the costs during each phase" [13], considers the environmental impact of a given material, since the extraction through production, use, recycling and what happens to the product after it is no longer used. "However, surveys of building practitioners have shown that LCA tools are not widely used to guide design development because the analyses are time-consuming, require burdensome data collection, and are poorly integrated with the design process" [14], despite the streamlined methodologies developed by Rodrigues et al. [15] and Hester et al. [16].

Following the LCA structure, the environmental preference method (EPM), created in 1991 by Woon/Energie in the Netherlands, compares construction materials and sorts them according to environmental preference. It takes into account the life cycle, in a process called "cradle to grave", from the extraction of the raw material to the waste from demolition. The main topics considered are: the shortage of raw materials, the ecological damage caused through the extraction of raw materials, energy consumption at every stage, water consumption, noise, emissions that destroy the ozone layer, global warming, and acid rain, health aspects, risk of natural hazards, maintenance, reuse and waste from demolition [17]. The aesthetic or cost are not involved in this evaluation, and the result of this preference is not an absolute value, but a ranking based on environmental impact. The reuse and recycling of materials are always preferable [17].

As such, the selection of the materials should take into account all stages of their life, such as manufacturing, processing, transportation, construction, maintenance, demolition, and recycling, but also the influence of the material on the behaviour of the building, concerning its relationship with their users and the surrounding environment.

Thus, it was decided in this paper to distinguish the two major stages in the life of buildings, the construction stage (from raw material extraction, passing through material production, until its application), and the occupation stage (from the use of the material to the end of its life) to better understand sustainability as a whole. Although the demolition stage creates a lot of waste, this stage can be avoided in most cases with maintenance and rehabilitation, lengthening the building's lifetime.

3 METHODOLOGY

The methodology (Fig. 1) was implemented in several fields [8], [9] and can be applied to any buildings [10], [11], providing they have similar characteristics, allowing the comparison between them.

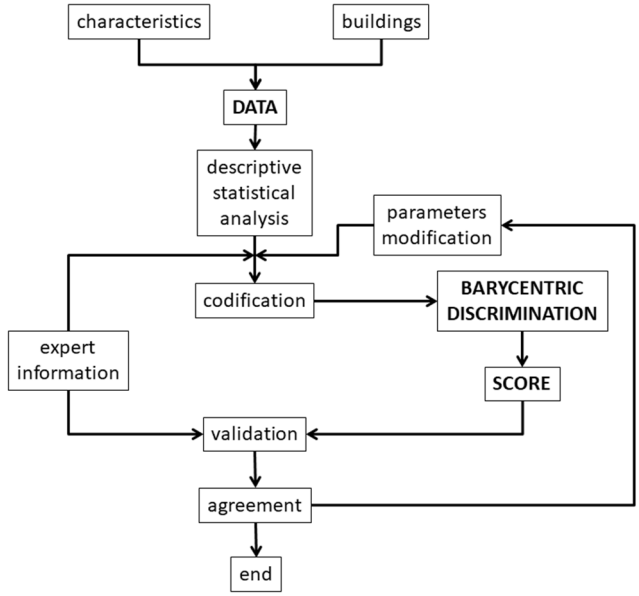

Figure 1: Schematic representation of the methodology. *(Source: Adapted from Ribeiro [8].)*

The first step is defining the characteristics (attributes, categories, or variables) that will be included in the analysis and selecting the buildings to assess. The data collection can be triggered by observation or experimentation, by surveys or other processes, providing samples vs. characteristics (variables), followed by descriptive statistical analysis.

In order to submit all the variables (quantitative and qualitative) to the algorithm, they should be codified in a disjunctive complete matrix [18].

Applying subsequently the barycentric discrimination (BD) – an adaptation of correspondence analysis (CA) to the discrimination around poles that are the centre of gravity of the starting attributes [8], [9] – to defining the extremes of the quality scale (discriminant

axis), the coordinate of the individuals' projection on this scale is a quantitative representation of quality (score).

The results are compared with more information, later obtained from unknown or random individuals taken from the data set in order to modify some parameters, thus resuming the entire process until the score is calibrated, validating the approach and methodology and the consequent use of the score as an assessment tool.

4 CASE STUDY

The eastern part of Lisbon was a rural area until industrialization in the first decades of the 20th century. After the deindustrialization process, the site was contaminated, mainly on soil and water, and served as a deposit to containers and fuel tanks.

The site was therefore an area available for urban renewal, using sustainable guidelines. The location for the EXPO'98 (the 1998 Universal Exhibition) was, therefore, a consensus due to: the need to revitalize the eastern part of Lisbon; the fact that it was a large plain on a riverfront; the potential for transformation into a city's new centrality, accessible by major roads and a new bridge over the river Tagus and, finally, the potential for public transportation with the airport, train, and subway nearby. The EXPO'98 located in the area now called Parque das Nações, created challenges for sustainable urban development, and was used for experimental concepts like reducing the consumption of energy or implementing alternative energy supply, in order to minimize the economic and environmental costs. In Calixto [19] and Cabral de Mello and Almeida [20] more details and measures applied in the area could be seen.

All the innovative solutions have contributed to the Parque das Nações area being recognized as an international case study, and the largest revitalization project design held in Lisbon since the 1755 earthquake. The area is a paradigmatic case study of urban regeneration and new construction, allowing assessment of the state of recent construction in Portugal.

The buildings selected for the study are distributed along the length of the entire area of the Parque das Nações and are a representative sample of the area. Thirty buildings (twenty residential buildings and ten office buildings) were selected (Fig. 2). The data was collected through direct observation of the buildings, information found at the Municipal Archive of Lisbon, the ADENE (Portuguese Energy Agency) Buildings Energy Evaluation, and documentation published on the internet [21]. The photographs of the buildings were obtained through the feature "Street View" of the Google Earth [22] platform. In this process, there were some constraints, such as the scarcity or uncertainty of information in the documents consulted, difficult access to the interior of buildings, and the unavailability of all the information contained in the Buildings Energy Evaluation.

The fieldwork consisted in completing a form with information about the materials and assigning percentages to the amount of materials used in each building. The components defined in this form can be seen in Table 1 and were based on the evaluation performed by Appleton [23], adapted to the current building materials.

Despite the diversity of materials used in the buildings, they have, as common characteristics, the period of construction and structure type, which gives coherence to the methodology.

In order to apply the methodology, the materials used are ranked from the less to the high environmental impact (Table 1) and for both stages. This ranking is based on different principles such as: the environmental cost, the embodied energy, the material life cycle, the emissions to the atmosphere, and the damage they cause to human health or a combination of them.

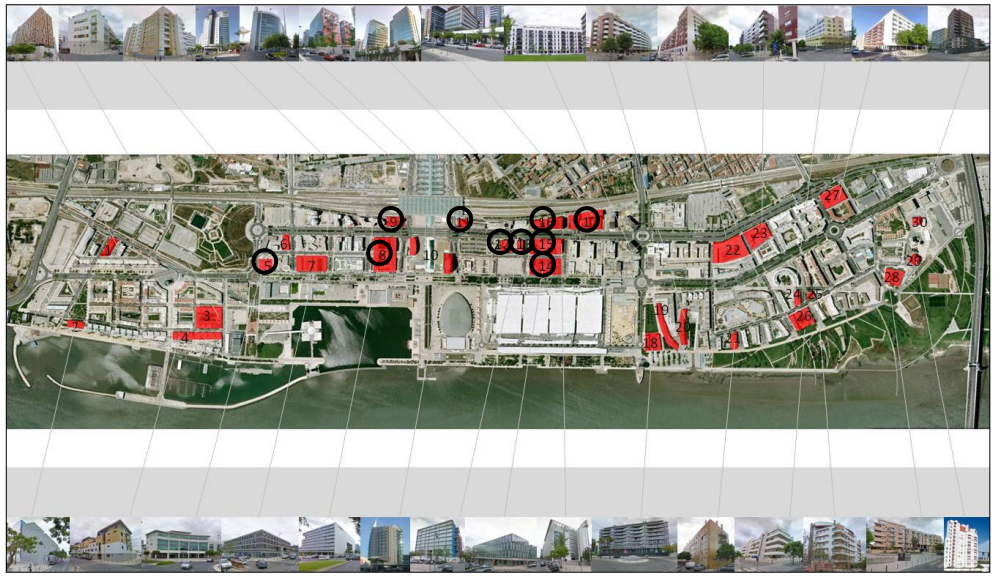

Figure 2: Location of the residential buildings (numbers in red patches) and office buildings (numbers and circles in red patches). *(Source: Adapted from Barreto [12].)*

A data matrix codified, crossing buildings versus materials, was built to synthesize the information collected (Table 2).

For each of the two sustainability assessments (concerning the construction stage, and the occupation stage), were added two lines (named CSUS and CNUS for construction stage and OSUS and ONUS for occupation stage) corresponding to the archetypes that define the extremes of the arbitrary scale of sustainability. CSUS and CNUS are, respectively, the best and worse material categories, from the sustainability point of view, for each building element at the construction stage. OSUS and ONUS have the same meaning for the occupation stage (Table 2).

Thus, these two lines of each stage (CSUS and CNUS for the construction stage and OSUS and ONUS for the occupation stage) were submitted to the barycentric discrimination algorithm [8] through software AnDad 7.12 [24] in order to create the discriminant axis, that defining the arbitrary scale of sustainability that has its extreme archetypes as CSUS and CNUS (the best and the worse possible scores, respectively) for construction stage, and OSUS and ONUS (the best and the worse possible scores, respectively) for occupation stage. The buildings from the data matrix (buildings vs. materials) are then projected as supplementary lines on the discriminant axis.

The buildings' projection coordinates on the discriminant axis are the sustainability score of each (re-scaled for easily understanding to 0 to 10), based on their materials, which provides a comparison and ranking among the several buildings of the sample, according to the methodology applied in this paper.

Table 1: Assessment's material preferences for each component and for both stages.

Components	Construction stage	Occupation stage
Structure	Concrete	Concrete
	Mixed	Mixed
	Metallic	Metallic
Rooftop structure	Concrete	Concrete
	Mixed	Mixed
	Metallic	Metallic
External walls	Brick masonry	Concrete
	Concrete	Brick masonry
	Glazing	Glazing
Internal walls	Gypsum board	Brick
	Brick	Gypsum board
Insulation	Without insulation	EPS
	Mineral fibers	XPS
	Thermal glass	Mineral fibers
	XPS	Thermal glass
	EPS	Without insolation
External wall coverings	Stone	Stone
	Wood	Ceramic
	Glass	Paint
	Paint	Glass
	Ceramic	Wood
Floor coverings	Stone	Stone
	Wood	Linoleum
	Linoleum	Ceramic
	Ceramic	Wood
Ceiling coverings	Wood	Gypsum board
	Gypsum board	Wood
	Paint	Paint
Rooftop coverings	Stone	Ceramic
	Wood	Concrete
	Concrete	Stone
	Ceramic	Wood
	Zinc	Zinc
Window frames	Wood	Lacquered metal
	Mixed	Aluminum
	Aluminum	Mixed
	Lacquered metal	Wood
Additional equipment	Water-saving equipment (–)	Water-saving equipment (+)
	Electricity-saving equipment (–)	Electricity-saving equipment (+)
	Solar panels (–)	Solar panels (+)
	HVAC (–)	HVAC (–)
	Home automation and steam distribution network (–)	Home automation and steam distribution network (+)

Table 2: Disjunctive complete matrix.

Building	Structure			…	Insulation					…	Additional equipment									
	Conc	Mix	Met	…	MF	TG	XPS	EPS	WI	…	Water sav		Elect. sav		Solar pan		HVAC		Domot	
											Y	N	Y	N	Y	N	Y	N	Y	N
1	1.0	0.0	0.0	…	0.0	0.3	0.7	0.0	0.0	…	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	1.0	0.0
2	1.0	0.0	0.0	…	0.0	0.3	0.7	0.0	0.0	……	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
10	0.0	1.0	0.0	…	0.5	0.5	0.0	0.0	0.0	…	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0
…				…						…										
29	1.0	0.0	0.0	…	0.0	0.2	0.4	0.4	0.0	…	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0
30	1.0	0.0	0.0	…	0.0	0.2	0.8	0.0	0.0	…	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	1.0
CSUS	0.9	0.1	0.0	…	0.25	0.1	0.05	0.0	0.6	…	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
CNUS	0.0	0.1	0.9	…	0.05	0.1	0.25	0.6	0.0	…	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0
OSUS	0.8	0.2	0.0	…	0.2	0.05	0.35	0.4	0.0	…	1.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0
ONUS	0.0	0.2	0.8	…	0.2	0.35	0.05	0.0	0.4	…	0.0	1.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	1.0

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5 RESULTS

Fig. 3 shows the sustainability score obtained by each building at the construction stage. The residential and office buildings are shown on the same graph, in order to compare the sustainability of both typologies.

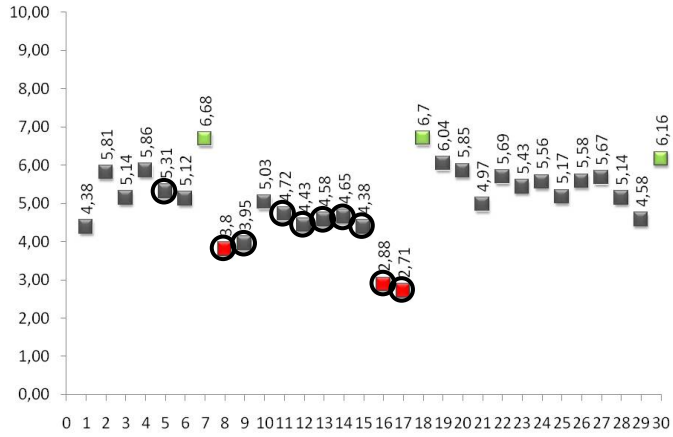

Figure 3: Sustainability scores for the construction stage of residential buildings (squares) and office buildings (squares and circles). *(Source: Adapted from Barreto [12].)*

In general, the residential buildings are best scores than the office buildings, stating a difference between typologies. This difference is not clearly defined, and there is a slight overlap between the residential and office buildings. Residential building #1 have a low score than four office buildings, and eight residential buildings have a low score than the top-ranked office building. The residential buildings obtain the three best scores and the office buildings obtain the three worse scores.

However, can be concluded that in terms of materials used in construction, residential buildings are more sustainable than office ones. This could be explained due to a higher amount of equipment, such as HVAC and home automation, in office buildings rather than in residential ones. Another reason for the lower scores achieved by the office buildings is concerning the architectural design options, where the curtain walls are predominant in the office buildings' façade.

However, as shown in Fig. 4, in a global analysis, the buildings studied did not show very high sustainability scores nor too low, and the large majority of buildings (26 buildings) had sustainability scores in the interval [4, 6]. Many buildings (21 buildings) present scores of 5 and 6, only seven buildings were classified under 5, and only two were classified as 7.

Fig. 5 shows the sustainability score obtained by each building at the occupation stage. The residential and office buildings are shown on the same graph, in order to compare the sustainability of both typologies.

The difference between residential and office buildings is still evident in the occupation stage. The office buildings, at the occupation stage, have significantly increased the sustainability scores, approaching the scores achieved by residential buildings. Three residential buildings (#3, #7, and #18) have a low score than six office buildings, and eighteen

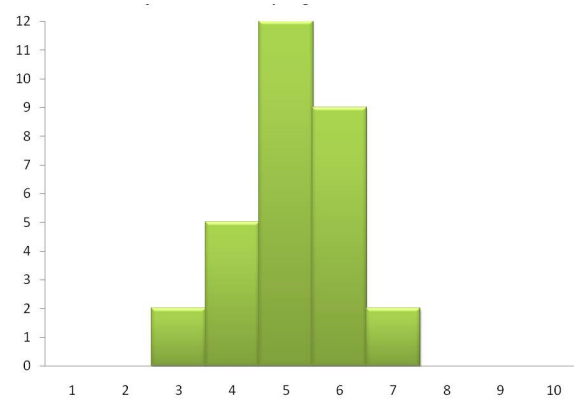

Figure 4: Distribution of sustainability scores for all the buildings, in the construction stage [12].

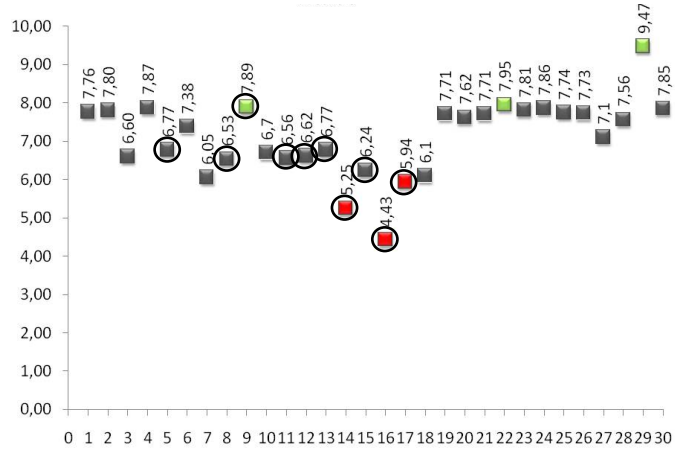

Figure 5: Sustainability scores for the occupation stage of residential buildings (squares) and office buildings (squares and circles). *(Source: Adapted from Barreto [12].)*

residential buildings have a low score than the top-ranked office building. However, the office buildings obtain the three worse scores, but an office building obtains the third best place.

However, contrary to expectations, the sustainability scores achieved by the office buildings are not clearly higher than the scores reached by residential buildings. It is thus demonstrated that the performance of buildings in the occupation stage can't be judged solely by the materials used, or that the variables most directly related to the occupancy should be more valued in the analysis, by introducing weights to assign more importance to these variables.

Fig. 6 shows the distribution of sustainability scores in the occupation stage for all the buildings, where it could be concluded that most buildings (23 buildings) have sustainability scores belonging to the interval [7, 8], i.e. with high values.

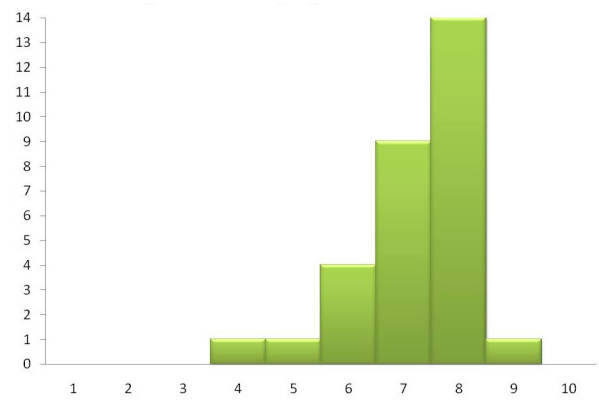

Figure 6: Distribution of sustainability scores for all the buildings, in the occupation stage [12].

Regarding all buildings in both phases, and calculating the average of two sustainability scores – construction and occupation stages – were obtained the results given in Fig. 7. It is also noticeable the difference between typologies, having the residential buildings achieve the best sustainability scores.

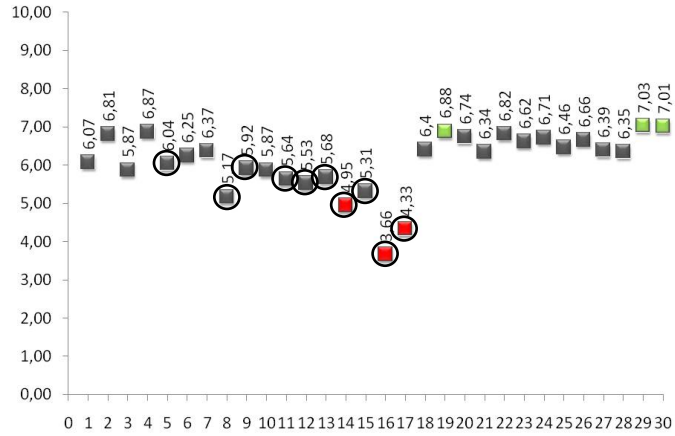

Figure 7: Sustainability scores of residential buildings (squares) and office buildings (squares and circles) for both stages. *(Source: Adapted from Barreto[12].)*

Residential building #29 – the Green Tower – is the better-scored building. This is not surprising, since it was one of the few buildings designed from the beginning with sustainability purposes, improving thermal comfort and reducing energy consumption. Residential building #30 also obtains a good score, due to its best classification in the construction stage, achieved through the use of covering materials with low embodied energy like natural stone.

At the bottom of the scale, office building #16 – the Zen Tower – have materials that contribute to its worst score like a metallic structure, large glazed area, metal roof, and HVAC system.

The distribution of sustainability scores, both in the construction and occupation stages can be seen in Fig. 8, which shows that the sustainability of buildings reaches medium–high values, with the large majority (25 buildings) displaying sustainability scores in the interval [6, 7].

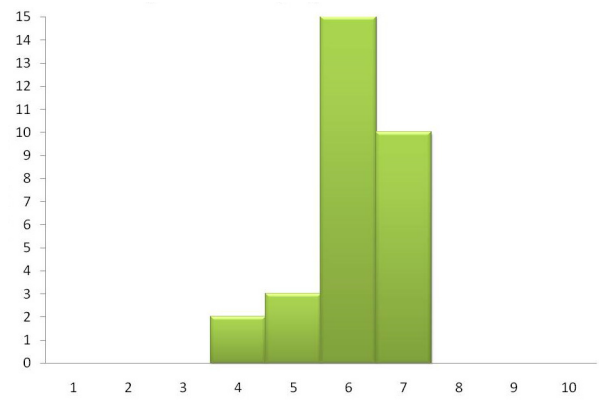

Figure 8: Distribution of the sustainability scores of all buildings, in the construction and occupation stages [12].

This analysis shows that it is possible to obtain a sustainability score in a simple way and easy understanding for professionals and non-professionals. It also shows the importance of materials choice and reaching a balance in the choice, taking into account the constructive factors such as embodied energy, landscape damage, and pollution, but also usage factors such as maintenance, durability, reuse, and recycling of materials.

It is recognized that the sustainability scores in the occupation stage should be the focus of more attention and require more tests, in order to be applied unambiguously.

The validation of this methodology through the monitoring of the construction or through the availability of this data with more precision by the municipal authorities would facilitate the data collection, leading toward the adoption of this assessment system for buildings. Thus, it is concluded that the methodology can be applied in this field of knowledge, being able to quantify the buildings sustainability, and establishing a decision support system for the architectural project design.

6 CONCLUSIONS

This paper highlights the importance of sustainability in the current context and the construction sector's impact on it.

It is implemented a methodology to quantify the buildings' sustainability in relative terms, basing the assessment on the materials' choice. Other criteria could be added to the set of variables used. The methodology is also useful in sustainability certification.

In some buildings it is perceived as the architecture and in particular, the selected materials can contribute to improving the environment. The buildings already included concerns about efficiency and comfort in their project design, which are shown through this analysis.

However, it is still possible to do better by introducing passive and even active measures such as solar energy and wind power.

The future of sustainability in the construction sector involves the environmental awareness of the project design team and the changing project design and construction habits. While there may have been significant steps in the path of sustainable construction, including the regulations aimed at improving the energy performance of buildings, it is important to emphasize that the path should also be covered in the preceding stages, i.e. before the buildings' construction. The Portuguese legislation is mainly focused on the use of the building, ignoring the constructive stage, equally important.

The findings presented in this paper are a starting point for further studies in other urban areas of Portugal, assessing the buildings and proposing solutions that improve the environmental performance of the construction sector.

REFERENCES

[1] WCED (World Commission on Environment and Development), *Our Common Future*, Oxford University Press: Oxford, 1987.

[2] Zabalza Bribián, I., Valero Capilla, A. & Aranda Usón, A., Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, **46**, pp. 1133–1140, 2011.

[3] Mourão, J. & Branco Pedro, J., *Arquitectura e Sustentabilidade Ecológica*, LNEC: Lisbon, 2005.

[4] EC (European Commission), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (COM(2011) 571 final) Roadmap to a Resource Efficient Europe, 2011.

[5] Kibert, C.J., *Sustainable Construction: Green Building Design and Delivery*, 3rd ed., John Wiley: Hoboken, NJ, 2013.

[6] BCA (Building and Construction Authority), *Sustainable Construction, Materials for Buildings*, Singapore, 2007.

[7] Mehta, H.S. & Porwal, V., Green building construction for sustainable future. *Civil and Environmental Research*, **3**(6), pp. 7–13, 2013.

[8] Ribeiro, J., Formulação de índices quantitativos com base na discriminação baricêntica. PhD thesis on Engineering Sciences, UTL/IST, Lisbon, 1999.

[9] Pereira, H.G., Sousa, A.J., Ribeiro, J.T., Salgueiro, A.R. & Dowd, P., *Correspondence Analysis as a Modeling Tool*, IST Press: Lisbon 2015.

[10] Barbosa, R., Avaliação sustentável da reabilitação em edifícios pombalinos de Lisboa. MSc thesis on Bioclimatic Architecture, FA-UTL, Lisbon, 2007.

[11] Ribeiro, J. & Barbosa, R., Degree of sustainability in rehabilitated "Pombalino" buildings in Lisbon. *Sustainable Architecture and Urban Development,* eds S.M. Fortea & J. Al-Qawasmi, vol. 2, CSAAR (Center for the Study of Architecture in the Arab Region) Press: Tripoli, Libya, pp. 441–456, 2009.

[12] Barreto, A., Avaliação da Sustentabilidade de Edifícios: Parque das Nações. MSc thesis on Architecture, FA-UTL, Lisbon, 2010.

[13] MIT CSHub, Buildings life cycle assessment (LCA). https://cshub.mit.edu/buildings/lca. Accessed on: 12 Apr. 2022

[14] Saunders, C.L., Landis, A.E., Mecca, L.P., Jones, A.K., Schaefer, L.A. & Bilec, M.M., Analyzing the practice of life cycle assessment: Focus on the building sector. *J. Ind. Ecol. Journal of Industrial Ecology*, **17**(5), pp. 777–788, 2013.

[15] Rodrigues, C., Miller, T.R. in collaboration with Gregory, J., Kirchain, R., Streamlined embodied LCA of residential buildings. Research Brief MIT CSHub, Issue 4, 2015.
[16] Hester, J., Miller, T.R. in collaboration with Gregory, J., Kirchain, R., Streamlined life cycle assessment of buildings. Research Brief MIT CSHub, Issue 1, 2016.
[17] Anink, D., Boonstra, C. & Mak, J., *Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment*, James & James: London, 1996.
[18] Nakache, J.-P., Influence du codage des données en analyse factorielle des correspondences. *Revue de Statistique Appliquée*, **XXI**(2), pp. 57–70, 1973.
[19] Calixto, L., Arquitectura e urbanismo sustentável: um estudo na zona oriental de Lisboa. MSc thesis on Architecture, UTL/IST, Lisbon, 2008.
[20] Cabral de Mello, D. & Almeida, M.G., Urban design and building for a sustainable neighborhood in Lisbon, Portugal (1994–2009): PP4 EXPO'98 urban renewal project. *Sustainable Architecture and Urban Development*, eds S.M. Fortea & J. Al-Qawasmi, vol. 2, CSAAR (Center for the Study of Architecture in the Arab Region) Press: Tripoli, Libya, pp. 425–440, 2009.
[21] Portal das Nações, http://www.portaldasnacoes.pt/. Accessed on: 22 Apr. 2010.
[22] Google Earth, http://earth.google.com/intl/pt/. Accessed on: 24 Apr. 2010.
[23] Appleton, J., *Reabilitação de Edifícios Antigos: patologias e tecnologias de intervenção*, Edições Orion: Lisbon, 2003.
[24] CVRM/CERENA/IST, Software AnDad, version 7.12, Lisbon, 1989, 2002, 2012.

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CLOGGING OF HONEYCOMB CATALYSTS DURING STOVE OPERATIONS

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ABSTRACT
This research paper describes the pressure loss of the honeycomb catalyst with very high cell density caused by a gradual clogging by particulate matter produced during the real biomass stove operation. The chosen catalyst was placed in the flue gas duct right at the flue gas outlet of two combustion units. Experimental combustion tests were carried out on two stoves (automatic pellet stove and wood log stove). Both stoves were connected to real chimney with ceramic flue gas path creating real chimney draught to simulate real home use of the units. During the tests, the static relative pressure at the catalyst inlet and at the catalyst outlet was measured, from which the pressure loss of the catalyst was determined. During both long-lasting combustion tests, problems with the clogging of the catalysts occurred (after several days of operation). These problems may cause significant safety risk, which was to be solved. Consequently, the decreasing influence of catalyst on mass concentration of carbon monoxide (CO) during the catalyst clogging was observed. Obtained results confirm the importance of finding an appropriate connection between chosen catalyst and newly produced combustion equipment. Consequently, the obtained results confirm the importance of solving the clogging problem by installing the catalysts as the retrofitting systems for old combustion units in flue gas duct in some kind of easy cleanable bypass, such as the rotation one, or by using catalysts with lower cell density.
Keywords: catalyst, stove, biomass, combustion.

1 INTRODUCTION

Nowadays, air pollution is a serious and intensively debated global issue. One of the sources of the air pollution is the combustion of solid fuels, which produces gaseous and particulate pollutants. More than 2.7 billion people in the world heat their homes by combustion of biomass in small burning equipment [1]. As there are almost 26 million used stoves in Europe, the individual states and European Union are constantly issuing new regulations for maximum amount of pollutants emitted from mentioned equipment into the air [2]. These regulations are progressively becoming more stricter and manufacturers of the combustion equipment must continuously improve the design of their products to comply with all regulations.

The changes of combustion equipment, from the design point of view, which prevent the formation of pollutants, are called primary measures. The primary measures are: better combustion air distribution in combustion chamber, adjustment of physical and chemical properties of the fuel, optimization of air excess ratio, combustion chamber material, etc. [3]. The primary measures, which affect the combustion process quality and, consequently, can reduce the amount of pollutants in the flue gas, are not limitless from the technical point of view. Location of the wood-burning stove at homes (usually in the living room) causes another design limitation by necessary reduction of a flue gas leakage during the door opening and by secondary function of the stove – decorative element in the home (improving the quality of combustion process at the expense of the appearance of the stove is usually not desirable) [4].

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Secondary measures can partially solve the described problem. Secondary measures are those which treat already generated flue gases (usually behind the combustion chamber) in order to reduce the mass concentrations of pollutants, such as electrostatic participates or catalysts. In general, a catalyst is a substance that participates in chemical reactions, accelerates them and helps them to proceed, as, for instance, in synthesis of higher hydrocarbon compounds (so called liquefaction) [5]. Catalysts used in the field of small-scale stoves stay unchanged after the chemical reaction (presumption of heterogenous catalysts' behaviour) [6].

In case of small combustion unit, the catalyst can be used in combination with a new combustion unit to comply with all regulations, or it can be used in old combustion units as a retrofit. The catalyst used in the combustion unit consists of the body, the wash coat and catalytic material. The catalysts body is usually ceramic or metal monolith with honeycomb structure. The washcoat is a layer of material with large surface area, such as titanium dioxide, silicon dioxide, aluminium oxide, etc. The catalytic material is made of precious metals, mainly platinum, palladium or rhodium [7]. These precious metals are the catalytically active elements and are deposited on the washcoat layer. In the case of catalyst installation right into the combustion unit, the catalyst may be placed in the combustion equipment itself or in the flue gas duct. During the combustion unit operation, the catalyst allows or facilitates the oxidation reaction of CO to carbon dioxide (CO_2) and organic gaseous compounds (OGC) to carbon dioxide (CO_2) and water (H_2O).

During the combustion unit operation, vacuum, which sucks the flue gas from the combustion chamber, is created in the flue gas duct and in the chimney (in modern combustion units the flue gas fan or combustion air fan can affect the pressure ratio in the flue gas duct). The vacuum is caused by a difference in density between the hot flue gas and the cooler ambient air outside the chimney.

A catalyst located in the flue gas duct can be considered as an obstruction, which reduces the vacuum. Not only the catalyst, but any object in the flue gas duct causes a so-called pressure loss (pressure loss is a difference between the static pressure at inlet and outlet of the object). The static pressure at the catalyst inlet is higher (lower vacuum) than the static pressure at the catalyst outlet due to the catalyst pressure loss. The vacuum in the flue gas duct allows not only the flue gas to be drafted, but also ensures the combustion air supply. A reduction of the vacuum can cause disruption of the combustion process.

The catalyst is designed in a way that its pressure loss is not large enough to cause the negative effect described above. However, during the combustion process, particulate matter (PM) may be deposited on the surface of the catalyst. In case of not appropriate catalyst usage in combination of not appropriate flue gas temperature and in combination of high mass concertation of particulate matter in the flue gas, the catalyst could gradually become clogged and its pressure loss increases. In the worst case, the catalyst can become completely clogged.

This study is aimed on flue gas pressure loss considering the catalyst's clogging by its operation in real flue gas environment.

2 MATERIALS AND METHODS

2.1 Fuel

Two types of fuel were used for the combustion tests. Wood briquettes were used for the tests with a manually loaded wood log stove. The briquettes were made from spruce sawdust and their elemental composition is shown in Table 1. The net calorific value of the briquettes was 17.01 $MJ.kg^{-1}$. Their diameter was 90 mm and length 300 mm. A1 class wood pellets were

used for the tests with automatic stove. The pellets were mainly made from spruce wood and their elemental composition is shown in Table 2. The net calorific value of the pellets was 17.65 MJ.kg^{-1}. The pellets were approximately 6 mm in diameter and 10 to 45 mm in length.

Table 1: Elements composition of used briquettes in raw state.

Element	Chemical symbol	Mass fraction (%)
Carbon	C^r	46.17
Hydrogen	H^r	5.37
Nitrogen	N^r	< 0.20
Oxygen	O^r	38.87
Sulphur	S^r	< 0.02
Water	W^r	8.58
Ash	A^r	0.79

Table 2: Elements composition of used pellets in raw state.

Element	Chemical symbol	Mass fraction (%)
Carbon	C^r	47.53
Hydrogen	H^r	5.7
Nitrogen	N^r	< 0.20
Oxygen	O^r	40.25
Sulphur	S^r	< 0.02
Water	W^r	6.05
Ash	A^r	0.25

2.2 Combustion unit

Two types of combustion units were selected for the tests. The first type of combustion unit was an automatic, wood pellet stove. This stove was equipped with a flue gas fan. The second type was the manually loaded, wood log stove, which was not equipped with any element for affecting pressure draught such as flue gas fan or combustion air fan. A detailed description of both combustion units is given in Table 3. The chosen combustion units were not designed for the catalyst installation originally.

Table 3: Description of the tested stove.

Parameter	Stove 1	Stove 2
Heat input	6.15 kW	9.8 kW
Feeding	Automatic	Manual
Fuel consumption	1.28 kg.h^{-1}	2.07 kg.h^{-1}
Fuel consumption	Wood pellets	Wood briquettes
Average flue gas temperature	268°C	452°C
Flue gas flow rate	19.26 m^3·h^{-1*}	16.38 m^3·h^{-1*}

Note: * = related to STP conditions.

2.3 Tested catalyst

For the experimental testing, a cylindrical (145 mm in diameter) honeycomb catalyst was chosen. This catalyst was produced for stove flue gas purification. The catalyst has a steel body, the surface of which is covered with a layer of aluminium oxide (Al_2O_3). At the surface of the catalyst, platinum (Pt) was applied as an active element. This catalyst was chosen for its high number of cells per square centimetre (inlet surface of each cell was very small), which causes relatively high flue gas pressure loss in comparison to other usually used catalysts for this application. Therefore, the worse conditions in terms of clogging by particulate matter were ensured. Detailed description of the catalyst is given in Table 4. A cleaned catalyst (without particulate matter) is shown in Fig. 1.

Table 4: Description of the used catalyst.

Body material	Steel
Carrier	Al_2O_3
Active compounds	Pt
Diameter	0.145 m
Height	0.02 m
Active surface	0.508 m^2
Number of cells	31.8 $cells \cdot cm^{-2}$

Figure 1: Honeycomb catalyst before combustion tests.

2.4 Measuring system for a flue gas analysis

The volume fraction of oxygen (O_2) in the flue gas was determined with a continuous analyser which works on the principle of determining the paramagnetic properties of the flue gas. The volume fraction of CO, CO_2 and nitric dioxide (NO_2) were determined by another continuous flue gas analyser which works on the principle of infrared absorption. The volume fraction of OGC was determined by a continuous flue gas analyser, which works on the principle of flame ionisation (FID). All instruments were justified before the start of the measuring each measuring day.

In case of the automatic pellet stove and the wood log stove, the catalyst was placed 450 mm and 100 mm, respectively, from the stove outlet into the flue gas duct. The diameter of the flue gas duct between the combustion unit and the chimney was 150 mm. In flue gas duct of each combustion unit, two measuring points were prepared at the catalyst inlet and at the catalyst outlet. The static pressure of the flue gas was measured at both measuring points, continually. Flue gas analysis with evaluation of catalysts conversion rate was held occasionally. Flue gas samples for the analysis were sucked from the same measuring points.

The flue gas duct was further connected to the chimney. Detailed description of the used chimney was published by Ryšavý et al. [8]. The location of the catalyst in the flue gas duct and the distribution of measuring points for Stove 1 and Stove 2 are shown in Fig. 2.

Figure 2: Experimental set up of pressure loss test of Stove 1 and Stove 2.

3 RESULTS AND DISCUSSION

The combustion tests were aimed at determination of the degree of clogging and pressure loss change of the catalyst during combustion unit operation. The catalyst pressure loss was

calculated from the static pressure, measured at the catalyst inlet and at the catalyst outlet. In addition, the catalyst clogging effect on the conversion rate of CO in the flue gas was determined.

3.1 Test with Stove 1

The testing of the catalyst installed in the flue gas outlet of the Stove 1 was carried out for 8 test days. Each test day began with switching on the flue gas fan and the fuel being ignited manually by a propane-butane burner. The flue gas fan was set at a constant speed for all test days. At the end of each test day, the exhaust fan was turned off after the flame was extinguished.

The static pressure curves at the catalyst inlet and at the catalyst outlet are shown in Fig. 3 as well as the evaluation of pressure loss. As can be seen, the static pressure at the catalyst outlet was constant throughout all the test days; this was caused by a constant flue gas temperature. After warming up the stove and the chimney in the first testing day, the static pressure at the catalyst inlet was −8 Pa. In the second day of testing, the static pressure at the catalyst inlet was still below 0 Pa and the evaluated pressure loss was lower than the static pressure at the catalyst outlet. During the third day of the testing, the static pressure at the catalyst inlet exceeded 0 Pa and continually increased. The pressure loss value exceeded the static pressure at the catalyst outlet. In the following days of testing, the static pressure at the catalyst inlet and the pressure loss continued to increase. The ever-increasing pressure loss was caused by the gradual clogging of the catalyst by the particulate matter. On day eight of the test, a static pressure of 35 Pa was measured at the catalyst inlet and the pressure loss was evaluated to 50 Pa, both values still increasing. The catalyst was not completely clogged even after eight days of testing. This was probably due to the oversized flue gas fan, which did not allow further deposition of the particulate matter on the catalyst.

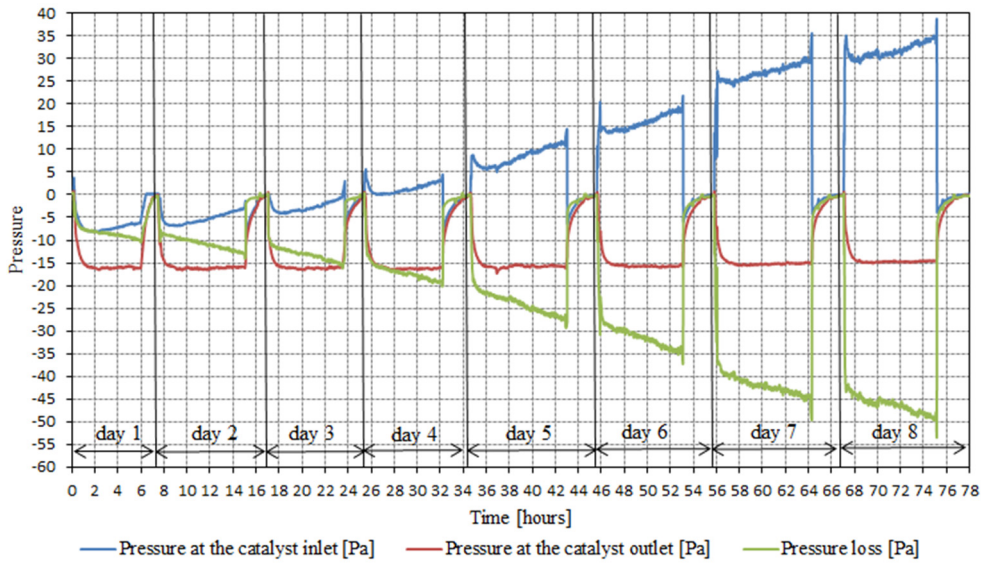

Figure 3: Course of all the measured pressures during the combustion tests provided with Stove 1.

Oversizing of the flue gas fan is also connected with high volume fraction of O_2 in the flue gas during the standard operation of the Stove 1. Since the pressure loss of the catalyst was continuously increasing and the flue gas duct used for experimental setup was not made for usage in the overpressure condition, the experimental test on the automatic pellet stove was terminated for safety reasons. In addition, due to the overpressure of the flue gas in the flue gas duct, a flue gas leakage was occurring at the connections between the flue gas duct sections. After the end of tests, the catalyst was removed from the flue gas duct and was cleaned from the settled particulate matter. A cleaned catalyst with the removed particulate matter is shown in Fig. 4.

Figure 4: Cleaned catalysts with the removed particulate matter after Stove 1 tests.

3.2 Test with Stove 2

Testing of the catalyst installed right at the Stove 2 outlet was carried out over four test days. Each test day started with the ignition of 1 to 2 kg of beech chips in the combustion chamber. The beech chips were used for ignition of the stove only. After the stove was ignited, one briquette was added to the combustion chamber. Due to the size of the combustion chamber, the briquette was halved. The burn time of one briquette was approximately 1 hour and 20 minutes. Three or four briquettes were burned each test day. The static pressure curves at the catalyst inlet and at the catalyst outlet and the evaluated pressure loss are shown in Fig. 5. As can be seen, the static pressure and pressure loss curves are similar during the first three test days. The vacuum at the catalyst outlet was slightly higher than the catalyst pressure loss. The small peaks in the static pressure curve at the catalyst outlet were caused by the change in flue gas temperature during the combustion periods.

At the beginning of the fourth testing day, beech chips were ignited manually inside the combustion chamber by the propane-butane burner as always. In the first 20 minutes of stove operation, the flue gas temperature increased and the static pressure at the catalyst inlet and at the catalyst outlet decreased. From the 20th minute of the burning process, the static pressure at the catalyst inlet started to increase up to +2.3 Pa. The pressure loss of the catalyst (−9.3 Pa) exceeded the static pressure at the catalyst outlet (−7 Pa). When the overpressure at the catalyst inlet was reached, the flue gas stopped flowing through the catalyst and the flame in the combustion chamber was smothered. The flue gas began to leak from the combustion chamber through the sealing between the stove door and the stove wall into the test room. Opening the stove door made the accumulated flue gas roll out of the combustion chamber and the fuel began to burn again with a visible flame (consequence of increase of oxygen mass fraction in combustion chamber). The state at the moment of the stove door opening is recorded in Fig. 6.

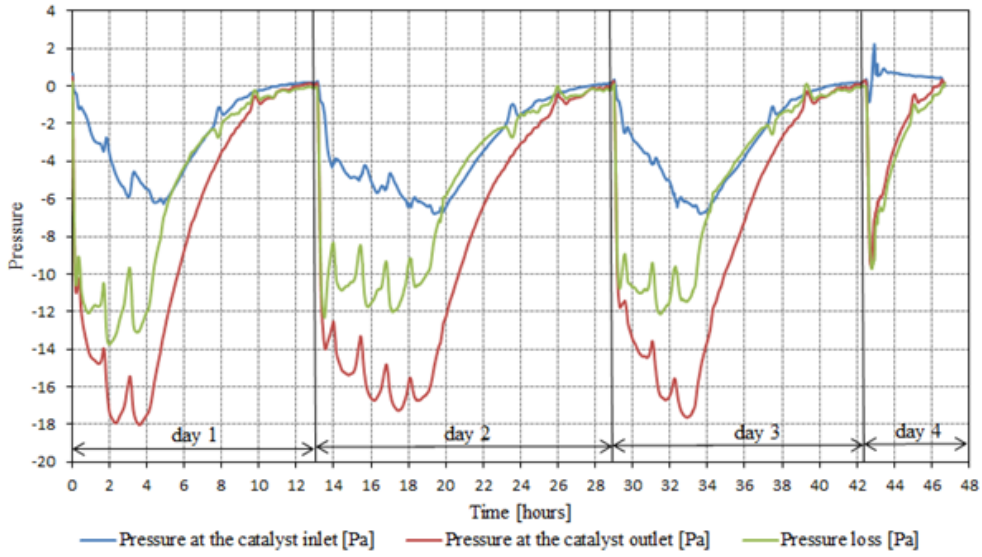

Figure 5: Course of all the measured pressure during the combustion tests provided with Stove 2.

Figure 6: Accumulated flue gas rolls out of the combustion chamber.

Figure 7: Clogged catalyst by particulate matter after four test days of Stove 2.

Results of these experiments show that the catalyst was clogged by solid particles after a few days of testing; this caused the creation of non-negligible flue gas overpressure in the flue gas duct at the catalyst inlet. In case of combustion unit usage without forced air or flue gas flow, due to catalyst blockage, the flue gas could not flow towards the chimney and the combustion air was not drawn into the combustion chamber. This issue caused the smothering of the flame and the leakage of combustion gases from the combustion unit and the flue gas duct. Overpressure in the combustion unit with flue gas fan was also created, but the flue gas was pressed through the catalyst by flue gas fan. The pressure, generated by the fan, was high enough for complete blocking of the catalyst by solid particles to be avoided in eight test days. It can be assumed that pressure loss of the catalyst exceeded the chimney draught at the end of third testing day; this created overpressure between the flue gas fan and the catalyst.

One of the catalyst characteristics that affects the pollutant's conversion rate is the surface area of the catalyst. The surface of the catalyst was gradually covered by particulate matter during the test. The solid particles gradually reduced the reaction area of the catalyst, which caused a decrease of the CO conversion rate. On three test days (during the Stove 1 testing), namely the 3rd, 6th and 8th, the flue gas composition at the catalyst inlet and at the catalyst outlet was analysed and the CO conversion rate was determined. On the 3rd day, the determined CO conversion rate was 38.9%, on the 6th day, 19.6% and on the 8th day, 8.5%. It is evident that the pollutant's conversion rate decreases with more particulate matter deposited on the catalyst surface.

It may seem that clogging of the catalyst is a purely negative process, as the CO conversion rate is reduced. Actually, the catalyst in the flue gas duct also works as a settling particulate matter precipitator. The deposition of the dust on the surface of the catalyst could help to decrease the mass concentration of particle matter in the flue gas. It is important to find the balance between particle matter separating and the catalyst clogging. The solution is

to clean the catalyst regularly or use a bypass device to prevent particulate matter deposition on the catalyst surface.

From the combustion tests carried out as part of this research, it was found that complete blockage of the catalyst, or a condition where the catalyst pressure loss was higher than the chimney draft, occurred in the natural draft stove during the first hour of stove operation when the chimney was not sufficiently heated, and the chimney draft was low. This effect, which occurred during our experimental tests, can be avoided also by using some kind of bypass device.

Bypass device works on the principle of reducing the amount of flue gas passes through the catalyst during the insufficient flue gas temperature, for example during the ignition phase. There are two commercially available designs. One of them is a bypass, mounted as a part the flue gas duct, which works on the principle of rotating the catalyst into two positions. In the first position, which is used when heating up the stove and chimney happens, the catalyst is (usually) in a vertical position (parallel to the flue gas flow direction) and the flue gas do not pass through the catalyst (just flows around it), but the catalyst is pre-heated, consequently. In the second position, the catalyst is in the operational, (usually) horizontal position (perpendicular to the direction of the flue gas flow) and the flue gas flows through the catalyst. The second bypass design is a device that is also mounted as a part the flue gas duct, but the catalyst is fixed in the horizontal position (perpendicular to the direction of the flue gas flow). Around the catalyst there are closable holes with flaps. When the flaps are open, during the heating up of the stove, the flue gas can flow through these holes instead of through the catalyst. This type of bypass does not ensure a complete flue gas flow outside the catalyst. The distribution of the flue gas between the bypass and the catalyst has not been studied so far, but it depends on pressure loss of the bypass and the catalyst. The first mentioned variant of bypass seems to be very suitable for the catalysts' installation in case of retrofitting of the old combustion equipment.

Another way to prevent the catalyst from clogging is to regularly clean it of particulate matter. Nowadays, catalysts in the field of small combustion equipment placed at the stove outlet have to be cleaned manually in certain period of time depending on catalysts' dimensions, mass concentration of particulate matter in the flue gas, flue gas temperature and also type of the installation (if the bypass is installed and used). Another way of cleaning a catalyst could be automatic cleaning, which would make the use of catalysts more convenient. Hammering the catalyst (under appropriate circumstances may be provided with the catalyst installed in a rotation bypass device) or cleaning with compressed air can be used as the suitable methods of cleaning. Further research will focus on ways of automatically cleaning catalysts.

In addition, it has to be mentioned that the chosen catalyst had very high cell density, which significantly shorted the time of clogging of the catalyst. Catalysts with lower cell density used in combination with modern combustion units with lower mass concentration of PM in the flue gas could be significantly less susceptible for the clogging.

4 CONCLUSION

For the pressure loss experimental tests on catalysts with high cell density, a catalyst with very tiny channels was used to simulate the worst possible conditions of catalyst's clogging. Already on the first day of the experimental test with the Stove 1, the catalyst pressure loss (14 Pa) was almost as large as the chimney draft (18 Pa). On day four of the test, the catalyst pressure loss (9.3 Pa) was greater than the chimney draft (7 Pa), resulting in the creation of an overpressure in the combustion chamber (2.3 Pa). The flame was extinguished, and the flue gas leaked into the surroundings of the stove.

The effect of clogging of the catalyst by particulate matter on the pressure loss of the catalyst can be seen in the results of experimental tests with automatic, pellet stove. During the tests, there was no variation in chimney draft (15 Pa), which was constant during all test days. The pressure loss of the catalyst then increased linearly each day (up to a value of 50 Pa). Despite the significant overpressure in the flue gas duct (35 Pa on the last test day), the flame was not extinguished due to oversized combustion flue gas fan that did not allow the catalyst to be completely clogged during the eight test days.

The deposition of particulate matter on the catalyst does not affect only the catalyst pressure loss. The deposition of solid particles on the catalyst fouls the catalytic active substance and reduces the pollutant's conversion rate. As part of the investigation, CO conversion rates were measured on an automatic pellet stove. The CO conversion rate was decreasing during the tests (38.9% on test day 3, 19.6% on test day 6 and 8.5% on test day 8).

Preventing or reducing the catalyst clogging rate can be done in various ways. The catalyst design has a significant effect on catalyst clogging. Smaller channels mean that higher pressure loss of the catalyst and, also, better particle separation occurs. At the same time, installing the catalyst closer to the combustion chamber can be another way of reducing the catalyst clogging rate. Higher temperatures can cause partial burnout of particulate matter on the catalyst. Other possibilities are bypass usage, or usage of different catalyst cleaning methods while the stove is in operation.

ACKNOWLEDGEMENT

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REFERENCES

[1] Mudgal, S., Turbé, A., Stewart, R., Woodfield, M., Kubica, K. & Kubica, R., *Solid Fuel Small Combustion Installations*, Boundary Element Technique: Ivry-sur-Seine, 2009.

[2] Ryšavý, R., Horák, J., Hopan, F., Kuboňová, L., Krpec, K. & Kubesaet, P., Comparison of catalysts in the point of view of pellet stove flue gas purification. *International Journal of Energy Production and Management*, **4**(2), pp. 124–133, 2019. DOI: 10.2495/EQ-V4-N2-124-133.

[3] Van Loo, S. & Koppejan, J. (eds), *Biomass Combustion and Co-Firing*, Earthscan: London, 2008.

[4] Chakraborty, R., Heydon, J., Mayfield, M. & Mihaylova, L., Indoor air pollution from residential stoves: Examining the flooding of particulate matter into homes during real-world use. *Atmosphere*, **11**(12), 1326, 2020. DOI: 10.3390/atmos11121326.

[5] Čespiva, J., Skřínský, J., Vereš, J., Borovec, K. & Wnukowski, M., Solid recovered fuel to liquid conversion using fixed bed gasification technology and a Fisher–Tropsch synthesis unit: Case study. *International Journal of Energy Production and Management*, **5**(3), pp. 212–222, 2020. DOI: 10.2495/EQ-V5-N3-212-222.

[6] Krpec, K. et al., Utilization of catalytic converters at wood combustion in small combustion appliances. https://vytapeni.tzb-info.cz/vytapime-pevnymi-palivy/10022-potencial-vyuziti-katalyzatoru-pri-spalovani-dreva-v-domacnostech. Accessed on: 25 Jan. 2022.

[7] Alshehri, A.A. & Narasimharao, K., Low temperature oxidation of carbon monoxide over mesoporous Au-Fe_2O_3 catalysts. *Journal of Nanomaterials*, **2017**, 8707289, 2017. DOI: 10.1155/2017/8707289.
[8] Ryšavý, R. et al., Condensation of water vapour in the flue gas path (Kondenzace vodní páry ve spalinové cestě). *Journal of Heating, Ventilation, Sanitation* (*Vytápění, větrání, instalace (VVI))*, **29**, pp. 193–200, 2020.

BIBLIOGRAPHIC REVIEW OF WATER SUSTAINABILITY ASSESSMENT IN CENTRAL AMERICA

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ABSTRACT
Due to the alarming increase in the water consumption rate, it has become fundamental to study ways to diagnose the needs of society assuring a sustainable development. This article covers the evaluation of water sustainability in Central America comprising Nicaragua, Costa Rica, Belize, El Salvador, Honduras, Guatemala and Panama. After analyzing the articles, it was found that Costa Rica and Nicaragua are the countries that have developed the largest number of publications on water sustainability. Among the researchers studied, it is possible to conclude that the use of sustainable politics and laws in the country's resources management plays a fundamental role in the sustainability of water, since a sustainable management responds to the population's complex social and economic reality, whereby the authors propose to implement new technologies to monitor the actual resources conditions and to improve the use and consumption of water by the population.
Keywords: bibliographic review, Central America, water sustainability.

1 INTRODUCTION

Sustainable development intends to meet the needs of the present without compromising the ability of future generations to meet their own needs [1]. Development was conceptualized from an economic perspective in the 20th century; however, the increasing study of the impact of human activity on ecosystems has generated an evolution in the way of conceiving development towards an integral perspective. Thus, the term "sustainable development" emerged in the document "Caring for the Earth", defined as "improving the quality of human life without exceeding the carrying capacity of the ecosystems that sustain it" [2]. One way to address this problem is to implement a methodology capable of interrelating the variables associated with the use of water resources of the society under study and variables of the ecosystem itself.

This is what many researchers try to achieve, evaluating different aspects of society and its processes. For example, the water nexus is present in processes like the treatment distribution and consumption of drinking water, wastewater treatment disposal, water use for energy generation, water management in coastal systems, water consumption in agriculture, water resource management in the watershed and, finally, government policies and actions related to resource management. Since the water nexus is so intrinsic to human existence, it is studied by different countries in various approaches, which are studied in this article at the regional level of Central America. The region of Central America comprises the countries of Nicaragua, Costa Rica, Belize, El Salvador, Honduras, Guatemala and Panama.

This article is presented in four sections: Section 1 describes an introduction of the topic, Section 2 contains the methodology used, Section 3 includes results and discussion, and finally, Section 4 presents the conclusions of this research.

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2 METHODOLOGY

2.1 Literature search strategy

This work was based on bibliographic research on the evaluation of water sustainability in Central America. This research extracts information from the database Web of Science, which constitutes a single multidisciplinary platform for searching and retrieving bibliographic information on works published in the most prestigious scientific journals, as well as tools for analyzing the publications themselves. The search developed uses the following searching equation "TS=(water sustainability) AND TS=(country)". The results were 142 items that were once filtered by selecting those classified as "water resources" and eliminating others which were in formats different from articles; for instance books, reports, etc. Also, excluding the articles which did not evaluate water sustainability, 41 articles remained. Once the articles have been selected, descriptive statistics are applied to analyze the distribution of the data. The process explained is described in Fig. 1.

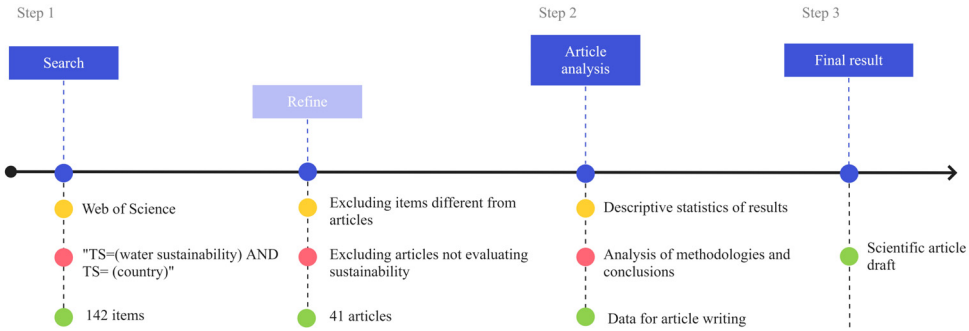

Figure 1: Methodology applied in the selection of articles.

2.1.1 Bibliography analysis

Once the articles to be examined have been established, it is possible to study their data to obtain the frequency of published articles and when these investigations of water. sustainability were developed. In addition, the location of the research made and the country that participated in the study. For example, Fig. 2. describes how many articles were published in each year. From Fig. 2 it is clear that research focusing on water sustainability, especially in Central America, has been increasing through the years making a peak between 2014–2016.

A geographic analysis was made to determine which countries had done more investigations into water sustainability. The results are presented per country in Table 1 and Fig. 3. From this it is concluded that Costa Rica and Nicaragua are the countries with the largest number of publications on this subject, it might be due to the collaboration of its citizens who conducted research during their postgraduate studies. Additionally, Guatemala and Honduras follow up with the most articles published, this fact stems from the continuous efforts of these nations to improve their water sustainability, especially in areas with environmental and social vulnerability, like rural areas.

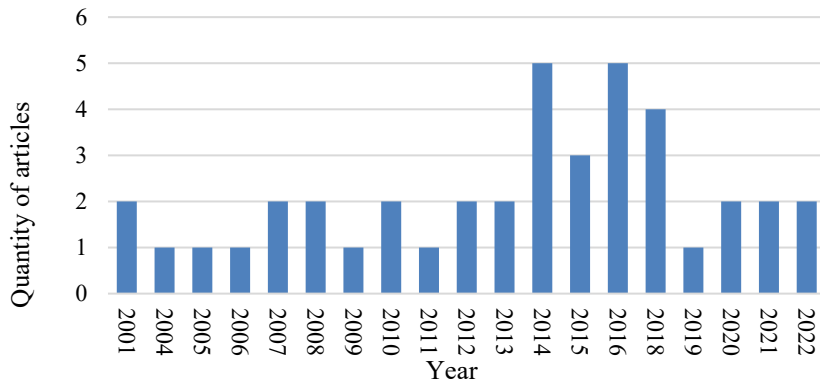

Figure 2: Publications on water sustainability by year of publication.

Table 1: Articles studied by country.

Country	Quantity	Searching equation	%
Belize	2	(TS=(water sustainability)) AND TS=(Belize)	4.88
Costa Rica	12	(TS=(water sustainability)) AND TS=(Costa Rica)	29.27
El Salvador	1	(TS=(water sustainability)) AND TS=(El Salvador)	2.44
Guatemala	8	(TS=(water sustainability)) AND TS=(Guatemala)	19.51
Honduras	7	(TS=(water sustainability)) AND TS=(Honduras)	17.07
Nicaragua	9	(TS=(water sustainability)) AND TS=(Nicaragua)	21.95
Panama	2	(TS=(water sustainability)) AND TS=(Panama)	4.88
TOTAL	41		100

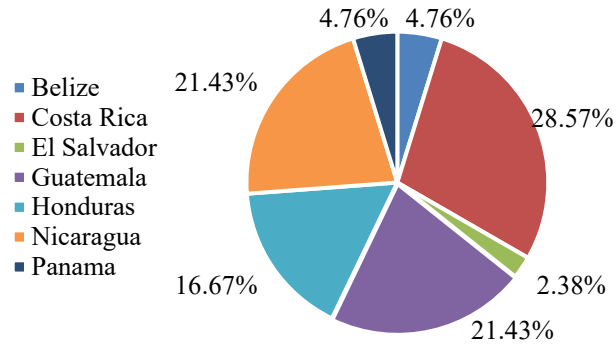

Figure 3: Articles studied by country.

The most recurrent research topics, as described in Table 2 and Fig. 4, are sustainability in drinking water, groundwater, wastewater treatment, integrated watershed management and water resource management. This may be due to the immediate needs of the population, which are the supply of drinking water and the treatment of their wastewater, which leads us to an integrated management of policies on the basins, where this resource is generated.

Table 2: Subject of articles.

Subject	Quantity	%
Watershed sustainability	9	21.95
Potable water sustainability	8	19.51
Governance of water	8	19.51
Sustainable agriculture	4	9.76
Wastewater sustainability	5	12.2
Groundwater sustainability	3	7.32
Archeological water sustainability	2	4.88
Coastal systems	1	2.44
Water for energy	1	2.44
TOTAL	41	100

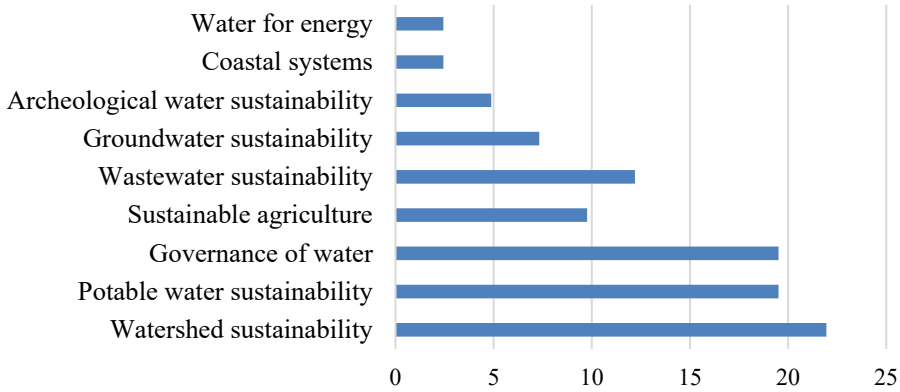

Figure 4: Article's subject by country.

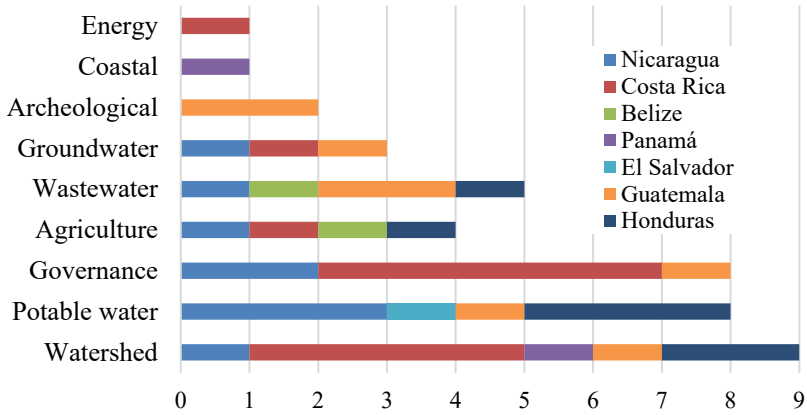

Figure 5: Article's subject by country.

3 RESULTS AND DISCUSSION

This section presents a comparison of results for all the articles discussed. As it is indicated above, the selected articles studied different subjects about water sustainability, in which each country led its methodology and investigation towards a specific view. To better cover the analysis, a study of each topic is presented individually as follows.

3.1 Wastewater sustainability

Wastewater is understood as water flow contaminated by human activities, including natural activities producing fecal matter, as well as agricultural activities with agrochemicals [3]. The discharge of wastewater directly into the environment not only impacts the water resource, but also the health of people with diseases such as diarrhea, causing deaths, especially in infants [4] reducing the quality of human and environmental life. The most vulnerable places are those outside the cities, which lack adequate sanitation, safe water supply, durable housing materials and/or adequate living space [5].

While the pursuit of sustainability in drinking water treatment systems seeks water quality standards (environmental feasibility) in an affordable manner (economic feasibility) with considerations in adapting people by their educational level [6], wastewater treatment achieves its sustainability by considering the social, economic, and environmental factors of the studied community. Many failures in the analyzed projects have their cause in maladjustment designs brought from other peripheries to the culture and society of Central America. For instance, not taking into account the geology, botany or meteorology of the place would make it difficult for the inhabitants to pay for the maintenance of the system due to lack of materials, funds or for the system to be deteriorated to the climate [3], [7].

Among the obstacles with the greatest impact when implementing a new system are: (i) users perception of the need for a change to be made, both in the domestic and agricultural sector [6]; (ii) lack of commitment of the State in following up the project and educating the population, as well as corruption that deviates project funds; (iii) absence of data for an efficient and sustainable design [3], [5]; (iv) lack of adaptation of the design to the community, taking into account factors such as climate [7].

The researches encompass methodologies to solve these obstacles such as (i) using social and behavioral change techniques for the adoption of the new wastewater treatment system, achieving to increase sustainability from 17% to 75% [6]; (ii) the use of stabilization ponds is proposed for being low cost in maintenance, generating jobs and an economic income by selling treated sludge, and using local plants [8]; (iii) in Sabogal et al. [7] they proposed the use of latrines, however, sustainability was not achieved due to a design that did not consider the climate and natural disasters of the site, as well as a deficiency in the education of the villagers; also Ali [5] emphasized that the point of treatment for wastewater can create problems of recontamination, in case of leaks, or cost surcharges in the collection system; while a centralized system, although requiring greater capital investment, can generate jobs and is more sustainable in the long term.

From the preceding, it can be established that sustainability in wastewater lies in the social, economic, political and environmental adaptation of the system to the user society. To achieve this adaptation, the designer must include a transition for the population, carried out through forums, interviews and training; it must also incorporate physical characteristics of the site into the design and empower the user to oversee the monitoring and maintenance of the system by them and the government

3.2 Groundwater sustainability

Groundwater has emerged as a source in the event of scarcity or impossibility of using surface water as a supply, especially for domestic or agricultural use. The main problems addressed in the selected articles are: groundwater contamination by mining, wastewater discharge and agrochemicals; overexploitation of the resource and saline intrusion, and access to groundwater [9], [10].

The search for sustainability, in groundwater, refers to the preservation of water supply, encompassing the quality and quantity of water, for different uses and consumption without compromising other communities in the present and future. This is achieved through the study of the impact that economic and social activities have on groundwater [9].

The proposed methodology encompasses population studies such as surveys, as well as subsurface exploration techniques for the extraction of the resource and evaluation of the studied area. What refers to the factors to be considered to evaluate sustainability, such as social-economic, political and environmental, studied as follows:

- In the social-economic context, the authors proceeded to conduct surveys of decision-makers within the population and users, especially farmers. The studies emphasized the importance of user participation and their power of voice within decision making at the political level [9].
- An active participation of the community, moved by the awareness of a water crisis, generates changes in practices, such as intensive agriculture to sustainable crops with efficient irrigation technologies, and the creation of organizations by the community.
- In the political context, the final impact of legislation and the enforcement of such regulations by the State of each country is highlighted. In countries where there was governmental support, the objectives were achieved and the actions acquired a greater impact not only in the community, but also as an opportunity for the whole country, facilitating sustainability over time with governmental support. However, other countries did not have the support of the government, whose legislation and execution turned to economic activities that compromised the quality of groundwater, despite the movement of the inhabitants against it [9].

The obstacles experienced achieving sustainability in groundwater were the lack of money, the scarcity of data, the lack of interest on the part of young people to maintain sustainability practices in the community, and the increasing change of land use violating protected areas. The authors recommended creating legislation to regulate land use and groundwater consumption, developing data collection for a better correlation of results, and evaluating the exploration methodology according to data availability and soil characterization [9]–[11].

3.3 Coastal water sustainability

A pilot coastal management plan was carried out in Panama; they proceeded to study and identify the areas of greatest risk and developed a management plan. Among the problems identified for water sustainability are the lack of a wastewater treatment system since the inhabitants discharge directly into bodies of water; lack of potable water in the area; and a solid waste disposal system that ends up in the bodies of water and contaminates the subsoil.

The plan could not be carried out due to a lack of financing and support from the State, so it was only possible to propose solutions. Another of the causes mentioned was the barrier

created by institutional instability due to changes of governors, which hindered the continuity of the project.

This led the author to conclude that water sustainability can only be achieved if the State is actively involved in it, since without this, the plans made by external consultants will not be implemented or will be limited [12].

3.4 Water sustainability in agriculture

Water management in agriculture not only affects rivers and groundwater – the last being the alternate source in times of drought – but also impacts the nutritional value of crops that contribute to the health of the population, social equity, and environmental well-being [13]–[17].

Most countries in Central America register approximately half of their inhabitants in rural populations [16] that usually develop an agricultural activity. However, only a small portion employs irrigation equipment (3%–4%) [16]. Hence the importance of bringing improvements to farming techniques to users, to make agriculture more efficient and sustainable. One of the techniques used was land leveling, which optimizes water distribution, reducing erosion in times of drought and flooding in times of rain, which increases production and expenses that impact the farmer, as well as reducing the amount of water used for agriculture; this type of system requires an investment capital that is recovered in the long term [17].

Along with more sustainable techniques, also Bro et al. [18] propose the implementation of cooperatives to empower farmers, as a solution to various problems present in their reality such as lack of roads or transportation networks [19], price and market information [20], and poor access to raw materials [21]. Cooperatives break down these barriers and gaps by increasing financing that boosts productivity and value of agricultural products [22], increases farmers' bargaining power and reduces transactional cost [23]–[26], help finance technologies for agriculture [27] which increases adoption to technology [28], helping to mitigate impacts due to climate [29]. The effect of the cooperative on producers was studied with the implementation of sustainable practices such as proper pest management, mulching, erosion prevention barriers, water retention techniques, water harvesting, use of soil analysis, green cover application, shade management, pruning, and stumping, where it was observed that cooperative members were more active in adopting these practices.

Another methodology proposed by Kammerbauer et al. [30] used aerial photographs to study the evolution of land use over 40 years in a watershed, while covering the social aspect through interviews at the same time, to survey the perception of the population over 20 years. This study showed a change in land use that increased the percentage of crops during the first years and decreased by half once agriculture was established; changes were observed in the forest cover due to its use as firewood, which regenerated naturally at a similar rate to that of deforestation. Therefore, it was advised to change the energy source to conserve the forest cover since this equilibrium may not resist population growth; also improve the monitoring of natural resources and increase the support fund by the State.

The obstacle to these methodologies lies in the corruption and institutional incapacity that manages the funds or supervises the implementation plans [31] as well as the lack of support in the private sector or NGOs [32]. Another obstacle is the marginalization of women, reducing their participation in the economy and decision-making, as well as the implementation of technologies. Likewise, the factor of education is fundamental, since it was observed that the more education the higher the probability of adopting a practice was increasing [18]. Lack of data and monitoring of resources hinders the design and

implementation of technologies [30]. Scarce financing to support investment capital. Lack of farm and land entitlement that makes it impossible to access credit to invest in new technologies or raw materials [18], [30].

Many of the methodologies propose the evaluation of sustainability through indicators of diverse natures such as energetic [17], social, economic and environmental [30], which reflects the complex process of achieving sustainability in a system that seeks to support agricultural activity, which feeds on natural resources, in demand of human presence.

3.5 Water sustainability in energy

This study took place in Costa Rica and Nicaragua, evaluating the water sustainability through ecosystem services. Ecosystem services are those resources provided by the environment for the development of the human activity, different ecosystems provide different resources and generate several users. This system is complex to represent, especially when ecosystem services are not taken into account in political decisions due to a lack of awareness and market failures [33].

The method proposed by Locatelli et al. [33] consists of mapping three factors: (i) spatial distribution of ecosystems and users, (ii) spatial relationship between them, and (iii) presence of filters or barriers between ecosystems and users [34]. Due to the lack of data, only the hydrological approach was performed, considering the various ecosystems of forests, pastures and crops. Generating maps of ecosystem services, achieving through the superimposition with vulnerability maps, determines the areas for conservation and restoration [33].

The results showed that, for Costa Rica, the restoration area coincided with the protection area, being the upper part of the watershed, due to human activities and topography combined with hydroelectric plants; however, for Nicaragua the areas did not coincide due to the lack of pattern for human activity and non-uniform resources. However, the author has insisted that the lack of data did not allow the generation of a reliable hydrological model to provide conclusions that would allow decisions on the economics of conservation and restoration [33].

4 CONCLUSION

Based upon this data it can be concluded that Costa Rica and Nicaragua are the countries with the largest number of publications on this subject, which might be due to the collaboration of their citizens who conducted research during their postgraduate studies. Also, Guatemala and Honduras follow up with the most articles published, this fact stems from the continuous efforts of these nations to improve their water sustainability, especially in areas with environmental and social vulnerability, like rural areas.

Water sustainability can only be achieved if all the variables that influence it are involved in the study. Along with this, one of the most determining factors is the population, since they are not only the users of the systems, but the ones responsible for their maintenance and operation in most cases. Many of the projects developed failed due to the lack of customization in the design of the infrastructure that did not fit the culture of the communities. On the other hand, another factor is the properties of the site, especially the climate, which influences the availability of water throughout the year, and can also generate landslides or floods that compromise the water systems life. Likewise, the politics and government of each country may support and guarantee the system or, it may corrupt and limit the success of the project. The latter is interrelated with the population, as the government provides the population with tools to develop their quality of life, such as

education and it also supports funds to help them access to technologies and infrastructure improvements.

According to water sustainability topics, we can emphasize that potable water sustainability was covered by most of the countries, whose articles proposed an improvement of the distribution web, especially for those rural communities who are more vulnerable to social inequality and resource scarcity; they also proposed new ways of treating water to achieve a sustainable process. Additionally, the wastewater treatment is reviewed, where some scientists describe critical problems in the wastewater plant treatment their country faced, such as low efficiency or an obsolete design which engages to sustainability of its functioning. To resolve it, a scientist proposed several improvements that could be implemented such as filters or try new treatment systems as stabilization ponds. Even though the articles intended to reach a sustainable way for water processing, the methods vary greatly. One factor that explains this behavior is the difference in population along with the culture and activities of each country involved in this research. Among all their concerns one that excelled is the sustainable management in watersheds. Furthermore, other factors that came out where deforestation and affections in different communities of one watershed, which resulted in the implementation of politics that assured the integrity of the ecosystems inside the watershed.

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REFERENCES

[1] Comisión Mundial sobre el Medio Ambiente y el Desarrollo, Our common future, 1987.
[2] UICN, PNUMA & WWF, Cuidar la Tierra, 1991.
[3] Ratner, B.D. & Rivera-Gutiérrez, A., Reasserting community: The social challenge of wastewater management in Panajachel, Guatemala. *Spring,* **63**(1), pp. 47–56, 2004.
[4] Prüss-Üstün, A., Bos, R. & Gore F.J. & Bartram, Safer water, better health: Costs, benefits, and sustainability of interventions to protect and promote health. *World Health Organization,* 2008.
[5] Ali, S.I., Alternatives for safe waer provision in urban and peri-urban slums. *Journal of Water and Health,* **8**(4), pp. 720–734, 2010.
[6] Prouty, C., Mohebbi, S. & Zhang, Q., Socio-technical strategies and behavior change to increase the adoption and sustainability of wastewater resource recovery systems. *Water Research,* **137**, pp. 107–119, 2018.
[7] Sabogal, R., Medlin, E., Aquino, G. & Gelting, R., Sustainability of water, sanitation and hygiene interventions in Central America. *Journal of Water, Sanitation and Hygiene for Development,* **4**(1), pp. 89–99, 2014.
[8] Oakley, S.M. & Mendonça, L.C., Sludge removal from primary wastewater stabilization ponds with excessive accumulation: a sustainable method for developing regions. *Journal of Water, Sanitation and Hygiene for Development,* **2**(2), pp. 68–78, 2012.
[9] Cuadrado-Quesada, G., Groundwater governance and spatial planning challenges: examining sustainability and participation on the ground. *Water International,* pp. 798–812, 2014.

[10] Lepper, E. & Elmore, A.C., Groundwater development in Lemoa, Guatemala. *Environmental Geology,* pp. 49–56, 2005.
[11] Mendoza, J. & Barmen, G., Assessment of groundwater vulnerability in the Río Artiguas basin, Nicaragua. *Environmental Geology,* pp. 569–580, 2006.
[12] Suman, D., Development of an integrated coastal management plan for the Gulf of San Miguel and Darien Province, Panama: Lessons form the experience. *Ocean and Coastal Management,* **50**(8), pp. 634–660, 2007.
[13] Valipour, M., Evolution of irrigation-equipped areas as share of cultivated areas. *Irrigation and Drainage Systems Engineering,* 2013.
[14] Valipour, M., Necessity of irrigated and rainfed agriculture in the world. *Irrigation and Drainage Systems Engineering,* 2013.
[15] Valipour, M., Increasing irrigation efficiency by management strategies: Cutback and surge irrigation. *ARPN Journal of Agricultural and Biological Science,* pp. 35–43, 2013.
[16] Valipour, M., How do different factors impact agricultural water management? *Open Agriculture,* pp. 89–111, 2016.
[17] Quirós-Vargas, J., Romanelli, T.L., Rascher, U. & Agüero, J., Sustainability performance through technology adoption: A case study of land leveling in a paddy field. *Agronomy,* pp. 1–16, 2020.
[18] Bro, A.S., Clay, D.C., Ortega, D.L. & Lopez, M.C., Determinants of adoption of sustainable production practices among smallholder coffee producers in Nicaragua. *Environment, Development and Sustainability,* pp. 895–915, 2019.
[19] Mwamakamba, S.N. et al., Irrigating Africa: Policy barriers and opportunities for enhanced productivity of smallholder farmers. *International Journal of Water Resources Development,* pp. 824–838, 2017.
[20] Nandi, R., Bokelmanna, W., Nithya, V.G. & Dias, G., Smallholder organic farmer's attitudes, objectives and barriers towards production of organic fruits and vegetables in India: A multivariate analysis. *Emirates Journal of Food and Agriculture,* p. 396, 2015.
[21] Fayet, L. & Vermeulen, W.J., Supporting smallholders to access sustainable supply chains: Lessons from the Indian cotton supply chain. *Sustainable Development,* pp. 289–310, 2014.
[22] Jena, P.R., Chichaibelu, B.B., Stellmacher, T. & Grote, U., The impact of coffee certification on small-scale producers' livelihoods: A case study from the Jimma Zone, Ethiopia. *Agricultural Economics,* pp. 429–440, 2012.
[23] Ma, W. & Abdulai, A., Does cooperative membership improve household welfare? Evidence from apple farmers in China. *Food Policy,* pp. 94–102, 2016.
[24] Bernard, T. & Spielman, D.J., Reaching the rural poor through rural producer organizations? A study of agricultural marketing cooperatives in Ethiopia. *Food Policy,* pp. 60–69, 2009.
[25] Hellin, J., Lundy, M. & Meijer, M., Farmer organization, collective action and market access in Meso-America. *Food Policy,* pp. 16–22, 2009.
[26] Holloway, G., Nicholson, C., Delgado, C., Staal, S. & Ehui, S., Agroindustrialization through institutional innovation Transaction costs, cooperatives and milk-market development in the east-African highlands. *Agricultural Economics,* pp. 279–288, 2000.
[27] Louhaichi, M. et al., Financial incentives: Possible options for sustainable rangeland management? *Journal of Environmental Management,* pp. 493–503, 2016.

[28] Wollnim, M., Lee, D.R. & Thies, J.E., Conservation agriculture, organic marketing, and collective action in the Honduran hillsides. *Agricultural Economics,* pp. 373–384, 2010.
[29] Jurjonas, M., Crossman, K., Solomon, J. & Baez, W.L., Potential links between certified organic coffee and deforestation in a protected area in Chiapas, Mexico. *World Development,* pp. 13–21, 2016.
[30] Kammerbauer, J., Cordoba, B., Escolán, R., Flores, S., Ramirez, V. & Zeledón, J., Identification of development indicators in tropical mountainous regions and some implications for natural resource policy designs: an integrated community case study. *Ecological Economics,* pp. 45–60, 2001.
[31] Bacon, C.M., A spot of coffee in crisis: Nicaraguan smallholder cooperatives, fair trade networks, and gendered empowerment. *Latin American Perspectives,* pp. 50–71, 2010.
[32] Ruben, R. & Zuniga, G., How standards compete: Comparative impact of coffee certification schemes in Northern Nicaragua. *Supply Chain Management: An International Journal,* pp. 98–109, 2011.
[33] Locatelli, B., Imbach, P., Vignola, R., Metzger, M.J. & Hidalgo, E.J.L., Ecosystem services and hydroelectricity in Central America: Modelling service flows with fuzzy logic and eexpert knowledge. *Regional Environmental Change,* pp. 393–404, 2010.
[34] van Noordwijk, M., Poulsen, J. & Ericksen, P., Quantifying offsite effects of land use change: filters, flows and fallacies. *Agriculture, Ecosystem and Environment,* pp. 145–155, 2004.

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ENVIRONMENTAL MANAGEMENT OF OIL EXPLORATION IN THE NIGER DELTA TOWARDS SUSTAINABLE CITY: THE NIGERIA CASE IN *OIL AT MY BACKYARD*

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ABSTRACT

This article examined the environmental management of oil exploration in the Niger Delta in order to ensure sustainable city with particular reference to Nigeria as extrapolated in the Nigerian novel, *Oil at my Backyard*. This research is informed by the generation of waste and pollution by the multi-national oil companies, the improper management of the wastes and the horrific consequences of the indecorous management. The theoretical framework of the research is Ecocriticism, a literary theory which applies ecological phenomena to the study of literature by examining the effects of human activities on the environment. The aim of this article was to investigate the portrayal of various forms of environmental mismanagement in the Niger Delta by Ejike in his novel, *Oil at my Backyard*. It is a case study that the detailed analysis was based on the novel, other critical works and available literature on oil exploration in the Niger Delta. As a case study, it examined the various spheres and manifestations of waste, its economic, social and health implication on the people and the city. The significance of the investigation lies in additional corpus of information on the discourse of human rights abuse by the multi-dollar oil companies in terms of negligence of corporate social responsibility on the host communities. The author discovered the insensitive disposition of the oil companies with regard to waste management which has resulted in attacks on the oil companies and their staff, destruction of aquatic life and emergence of militancy with its attendant effects on the city and other social and economic imbalances. The author recommended, among others, the development of sustainable mechanism towards waste management in collaboration with the host communities.

Keywords: environmental management, waste generation, pollution, environmental degradation, ecocriticism, sustainable city.

1 INTRODUCTION

The discovery of oil at Olobiri in the Niger Delta of Nigeria was greeted with pomp and pageantry, little did the inhabitants ever conceive that they were about to sit on a keg of gun powder. From the prospect of the oil to the eventual drilling in commercial quantity, it has been for the people a juxta positioning of booming prosperity and unfortunate dooming annihilation of their livelihood. Thus, the Niger Deltans especially the tripartite states of Rivers, Bayelsa and Delta, have had mouthful of the sweet bitter taste of oil exploration.

The Niger Delta embody ecosystems of mangrove swamps, large wetland, rain forest and fresh water swamps. According to Onyema [1], "the area comprises about 37 million spread in about 1,600 communities that harbour various tributaries…". Ken Saro-Wiwa, a bonafide indigene of Ogoni in Rivers State describes Niger Delta as:

> … one of the world's greatest ecosystem; Africa's largest and the world's third largest mangrove forest; the most expensive fresh water swamp in Western and Central Africa and Nigeria's major forest concentration of high biodiversity and the center of endemism [2].

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This autochthonous tributary defines the Niger Delta being the home of quantum oil and gas deposit. In fact, the massive and substantial deposits of oil and gas in "the Niger Delta contributes to about 98 percent of Nigeria's income and positions her as the sixth largest exporter of oil in the world" (Onyema [1]). Here, our search light is on the three states of Rivers, Delta and Bayelsa.

It is vital to note that Inno Ejike's *Oil at my Backyard* is not alone in the literary creation of oil exploration and its consequences on the Niger Deltans. Nnedi Okoroafor Mbachu's *Zahrah the Windseeker* (2007); Chika Unigwe's *The Phonix* (2007); Iheanyi Izuka's *The Travails of the Black Gold* (2001); Elechi Amadi's *The Great Pond* (1969); Amarie Majoro's *Suspended Destiny* (2007); Ojaide's *The Activist* (2006); Okpi Kalu's *The Oil Conspiracy* (1988); Ken Saro-Wiwa's *The Poisoner's J-ebs* and a host of others adumbrate the "ironic contradictions of the consequences of … exploitation by multinational companies" (Nwahunanya [3]). Eco literature of the Niger Delta is not literature for its sake but the ones that make substantially categorical statement on the socio-economic, political, environmental and other fundamental quandaries that do not only debase the region's flora and fauna but more importantly infringes on the host communities' inalienable right of livelihood. The degrading deprivation is eco-rooted in environmental mismanagement.

2 MANIFESTATIONS OF ENVIRONMENTAL FUMBLE

Oil at my Backyard [4] is principally an abundant testament of multinational oil company's negligence of not only corporate social responsibility but flagrant abuse of environmental management. The prototypal Onyenga Oil Company, Eluala Oil Company and Ricco International USA are hosted by Umuibe, Rumuma, Oduala and Ruga communities of Niger Delta. Prior to the oil prospection, the settlement of the oil companies and eventual permanent drilling of oil, these communities were archetypally peaceful with fertile agricultural farmland, fresh sea water and other naturally endowed biodiversities. Even their cultural festival such as Oghu Festival (p. 9) and other cultural etiquettes were intact and observed with concerted commitment and obeisance. The advent of oil exploration decimated their ecosystems and agrarian lifestyle. The recollection of Mr Onwuka, the village head of Oduala is quite informative of the impending predicaments his people is to face on sighting Mr Obidi in his Toyota four wheeled jeep:

> Onwuka remembered what happened to his in-law when oil was discovered in their village. Initially they had thought that God had answered their prayers by providing them with the liquid gold. No sooner had the oil companies started exploration than the devastation of their farmland commenced (p. 9).

True to the prophetic suspicion, under the pretence of already paid compensation and with the casual labour from the youths, "a large expanse of land which included some cassava farms" are cleared. The clearing of the peoples' cassava farms without prior notification depicts the company's insensitivity to the peoples' source of livelihood. The damage done to the cassava farms infuriated the women that their representative, Ada, emphatically states amidst heavy tears, "My husbands. Oh our cassava, our cassava farm was ravaged. Are we going to starve to death because we have oil at our backyard?" (p. 43). Even with the purported compensation paid, perhaps to the wrong hand which "did not get to the people for whom it was intended" (p. 42), the mindless destruction of the economic crop of people wallowing in abject poverty, women living in "a very swampy village with little or no motorable roads", a place with "no development or Federal Government presence" (p. 14) is provokingly unwarranted. A more responsible approach would have been to notify the people

with a deadline to harvest their cassava. Mr Obidi's pledge to pay insignificant sum of twenty thousand naira as compensation for the entire damaged cassava is an insult to their sensibilities as well as a ridicule of their social status. The women's demand for "one hundred thousand naira" (p. 43) is certainly not enough for their "cassava … our land and our oil" (p. 43) yet they cannot but accept it because they "do not want to starve before the next planting season", hence they "have many mouths to feed" (p. 43). Unfortunately and regrettably, Mr Obidi accepted and paid the ridiculous sixty thousand naira. The preposterous amount gravely bit the imagination of the women so much that "they felt like shedding tears …" (p. 45) as "the compensation was far below the cost of damage to their cassava farms", hence "the oil company also felled many palm trees and raffia trees" (p. 46) which serve as their major source of wine for refreshment and raffia used to make thatched roof for their houses (p. 46).

The insensitivity, indifference and environmental indecorousness of the oil company is further evident in gas flaring. The oil companies' reason to flare gas is because "they had no facility to re-inject it into the soil" even though "they would spend extra resources to flare the gas" (p. 79). The implication is that they are more concerned with their expenses than the peoples' lives and livelihood. Their wrong and poor value culture is frantically inhuman-oriented. Their infamous orientation amounts to savagery and barbarism. Not really that they do not know and understand the ravaging consequences of gas flaring on the people and its attendant environmental degradation but simply choose the part of cruelty. Thus, instead of seeking a public-spirited and meaningful solution, "they intensified gas flaring" (p. 79). The evidence of gas flaring is everywhere after the first rain so much that even the most illiterate villagers cannot but

> Noticed the unusual occurrence within their surroundings. The rain water was no longer drinkable. It was mixed with heavy carbon deposit. Those that went to the farm noticed that their clothes were painted black. There were traces of carbon monoxide in the atmosphere (p. 79).

The panacea, at least in the interim, would have been immediate and quick provision of portable pipe borne water to assuage the water needs of the people since their local source of water has been polluted. This would have been the remote measure to environmental management. But, of course, in their business-minded orientation, they would think of its cost effectiveness. Ayandale [5] points out that "environmental degradation from gas flaring, dredging of larger rivers, oil spillage and reclamation of land due to oil and gas extraction across the Niger Delta region cost about US$758 million every year". Yet, the exorbitant cost cannot exchange human life and equate the destruction of ecosystems, aquatic lives and other sundry consequences. To spend the money, and even more, to reclaim a land and preserve life defines a reasonable approach to environmental management.

The pipeline explosion at Rumuma brings to fore more aspect of indiscreet attitude of oil companies towards environmental management and the plight of the host communities and their inhabitants. The youths' grievances have degenerated into violence confrontations and attacks on oil facilities and installations. In its usual misplacement of its expected corporate responsibility it opted to building storage tank. Its option ended up exposing Eluala Oil Company's selfish and capitalist idiosyncrasy. The explosion resulting from excess pressure tragically consumes unquantifiable lives and properties. Unfortunately, an internationally multi-dollar oil company does not have adequate health facilities in its premises let alone for the host community. Ridiculously, "what the company had in its premises was a first aid post with only a nurse on duty" (p. 131). Sadly too,

> The nearest health care center was at the local government headquarters and was yet to be upgraded to a general hospital. There were no doctors on duty when the first batch of victims were brought in…. Many died before adequate medicare could reach them…. The hospital was inadequately funded. Most drugs were out of stock (p. 131).

Immediately after this catastrophically fatal incident, Eluala Oil Company "intensified their drilling efforts and were able to complete five additional wells" (p. 132) with no attention and plan whatsoever to pay compensation on the lost lives and properties as well as remedy environmental hazards caused by the explosion. Clearly, its basic "interest was drilling the oil and making profit with little concern for ecological consequences to the environment of the oil producing area" (p. 164).

The more worrisome dimension of the imprudent management of the environment is the lackadaisical attitude of the government. The lacklustre disposition of the government exacerbates the plight of the host communities of the oil companies. Government's betrayal manifests in the paltry compensation and payment of same through insincere and unpatriotic government officials. There is no systematic machinery to monitor the appropriation of the compensation. It is non-negotiable fact that oil companies actually paid compensation to the people for their farm land via the Mineral Development Agency. Mr Obi, Eluala Oil Company's representative states unequivocally that "compensation was dully paid after the survey for the cash crops…" (p. 42). The company is embarrassed on discovery that compensation never got to the people. Regrettably, instead of the government to track the misappropriation of the compensation, it rather send "some soldiers to protect the men sent to do the survey…. The did not bother to discuss with the villagers at the grassroots level…" (p. 42). All efforts the company made to get government accountable is futile. Consequent upon the report of Mr Obidi on the disruption of oil exploration and recommendation of "social amenities to calm the villagers' justified anger against neglect by the government" (p. 83); the Chairman, Eluala Oil Company laments, "we are looking forward to receiving our exploration grant from the government. Since we put our men and machinery to site, the government has not paid our fees…, we need government support to start the project at Oduala" (p. 83). Vindal [6] points out categorically that

> Since the inception of the oil industry in Nigeria, more than fifty years ago, there has been no concerned and effective effort on the part of the government, let alone the oil operators, to control environmental problems associated with the industry.

The futility and the peoples' despondent predicament is climaxed by the government's utopic and endless promises of the provision of basic amenities of good road, health care and pipe borne water and the blame game by the oil company. Mr Obidi rejects complete responsibility, "we are aware of your plight. The fault is not that of Eluala Oil Company. The delay is due to government red tape, and the snail speed at which the government carries out its programs" (p. 96). The fact here is that both the oil companies and the government lack the utmost sincerity, political will and commitment to ensuring environmental management. The evasion of their statutory responsibilities by government and oil companies is not, of course, without resultant effects.

3 THE CONSEQUENCES OF TRASHY ENVIRONMENTAL MANAGEMENT

The discovery and exploration of oil in the Niger Delta is, in fact, oxymoronically palpable. We see manifestation of good and bad, boom and doom, wealth and impoverishment and all other obvious contradictions. Nwahunanya [7] states succinctly that "the region is the symbol of the ironic contradictions of the consequences of capitalist exploitation by multinational economic interests teaming up with the local comprador bourgeois class". The graver reality in the case of Niger Delta of Nigeria is complete jettison and neglect of the "geese that laid the golden eggs" (p. 146). In fact, "what they have thought was a blessing had turned to be a curse" (p. 131). The overall aftermath of the abandonment ranges from economic downtroddenness, psychological disillusionment, environmental degradation, perennial health challenges and emerging activism with its attendant quandaries.

Ejike's *Oil at my Backyard* provides copious critique of a people with economic lowliness, a society impoverished by devastating oil exploration. The indigenes of Niger Delta are fundamentally agrarian whose economic lives essentially depend on land and water. The region is naturally endowed with mangrove forest, fertile and arable land as well as surface and underground water. The mangrove forests are their major source of wood and a variety of raffia palm species for subsistence farm practices. Fish farming is the peoples' primary and greatest occupation. Their raffia that grows freely along the swamps is their major sources of wine for refreshment while the raffia leaves are used to make thatched roof for their houses (p. 46). Unfortunately, the discovery and exploration of oil marks their historic economic downturn. The prospection of oil heralds the ravaging of their cassava plantation. It is economically debasing for them to see "their young cassava shoots levelled to the ground, and their leaves withered by the scotching afternoon sun" (p. 45). "The oil company had also felled many palm trees and raffia trees" (p. 46). The "drilling activities… polluted streams and the creeks. Our fishermen are coming back with empty baskets, as the fishes are being destroyed by pollution…" (p. 152). Also, "some sea birds, turtles and fishes were washed ashore floating on their backs. They have died of pollution to their environment. The fishermen were temporarily put out of business…" (p. 171). All these cannot but "impoverish our people…. They do not have working capital, and inflation has devastated their business…" (p. 151). Nwahunanya [7] captures the gravity of the economic deprivation and suffering of the people of the region, "as the land is exploited, so also are the people. As the land bleeds oil, so the people bleed tears in their abject poverty…." In the like manner, Onyema [1] bemoans the economic condition of the people, "… the people of the Niger Delta, who are fishermen and farmers, have been suffering from act of bioterrorism, oil pollution of land and waters, … hunger, diseases and poverty, as a result of the general destruction of their aquatic and terrestrial reserves".

Environmental degradation, asides the above economic catastrophe, results in perennial health challenges. The gas flaring and oil spills on the environment have devastating health implications. The gas flaring increases deposit of carbon monoxide in the atmosphere which makes their rain water undrinkable. The acid rain pollutes the land and makes their crops unconsumable. The consumption of polluted water and poisonous food translates into respiratory diseases and heart congestion (p. 167), miscarriages among women folk and impotence among men (p. 79) as well as spread of cancer (p. 199). Nwahunanya [3] notes other consequences of gas flaring and oil exploration such as "widespread scorching of vegetation… disappearance of foliage and overexposure of soil cover to harsh weather conditions, death of aquatic life and a destabilization of the ecosystem…, dietary short falls … and emission of large amounts of methane and carbon dioxide".

The loss of mangrove forest; the rivers that provide water for drinking, bathing, cleaning and fishing for both the dinner table and trading to make profit; drastic change of ecosystem and the entire biodiversity generate in the people psychological disillusionment. The reality of their hopelessness is dawn on them. Their consciousness is awakened to the point of seeking solutions to their problems through legitimate and illegitimate means. The emerging activism, grouping and regrouping into movements such as Movement for the Survival of Ogoni People (MOSOP); Movement for the Emancipation of Niger Delta (MEND); Niger Delta People's Volunteer Front (NDPVF); Niger Delta Liberation Front (NDLF) (Ibeanu [8] p. 9); Niger Delta Avengers (NDA); Adaka Boro Avengers (ABA); Niger Delta Greenland Justice Mandate (NDGJM), etc; hostage taking of company workers; capture and seizure of companies' barges, tugboats and fast boats; vandalization of companies' pipelines and other facilities (p. 187); militancy and oil thievery (bunkering) (p. 168, p. 172) become direct and indirect attack on the oil companies. All these are not without attendant perplexities and problems. The aftermaths range from military incursion, arrest and detention of purported culprits including innocent citizens (p. 186), reprisal attacks on military cantonment by angry youths and mobs, loss of lives and properties through explosions of adulterated kerosene and petrol (p. 192), social unrest and displacement, and massive death resulting from inferno from punctured oil pipes (p. 167).

4 CONCLUSION

It is quite unpropitious that discovery of oil and its exploration in commercial quantity turned calamitous owing to environmental mismanagement by multi-dollar and multi-national oil companies as well as government's indifference to the plight of the host communities. Although some insignificant efforts have been made by the oil companies in favour of the host communities such as building unequipped health centres, sinking of boreholes at Rumuma (p. 196) and provision of casual employment to the youths and other indigenes (p. 24, p. 77). On the part of the government, seemingly worthwhile strategic efforts have been made such as establishment of parastatals, commissions, committees and so on to manage the Niger Delta challenges but with little or no achievements. For instance, far back 1952, before independence, the government established Willink Commission to look into the problem of minorities which was a product of recommendation by Niger Delta Development Board (NDDB). Others were Niger Delta River Basin Authority (NDRBA) in 1967; Oil Mineral Producing Area Development Commission (OMPADEC) in 1992 which existed to 1999; Niger Delta Environmental Survey (NDES) in 1995; Niger Delta Development Commission (NDDC) in 2000 which exists till date; Niger Delta Peace Conference (NDPC) in 2007 and Niger Delta Technical Committee (NDTC) in 2008. In terms of maintaining security, there was Special Security Committee on Oil Producing Area (SSCOPA) in 2001 and Joint Task Force (JTF) in 2008.

Most unfortunately, all these exemplification of good intension and concerted effort yielded less qualitative output. The activities of the commissions were (and still are) riddled with corruption, insincerity, nepotism, poor implementation strategy and lack of political will to budget enough money for quality implementation in line with derivation principles. Ako [9] adds that the efforts "lacked sufficient elements of democracy, accountability, equity and active public participation of all stakeholders". Sixty six years (that is 1956) after discovery of oil in Niger Delta, the indigenes cannot boast of good medical health care, good road network, pipe borne water and other basic infrastructural amenities. Thus, the desired peace and infrastructural development have remained elusive.

5 RECOMMENDATIONS

The recommendations are necessary because if implemented will ensure not only sustainable city but more importantly sustainable communities, lives and sources of livelihood. The demands of the indigenes of the host communities from the government and oil companies are not really unsubstantial and too much: "compensation for everything…" (p. 43), "construction of good roads…" (p. 44), "a permanent employment…" (p. 79) for suitably qualified indigenes and youths (p. 95), "… portable water…" (p. 83), "… scholarship for local and international studies" (p. 87, p. 153) and "electricity and functional primary, secondary and tertiary schools" (p. 128). All these are predicated on the avowed conscious contentions that "the oil is at our backyard …. It is ours. It is God's gift to us and nobody should take it away from us" (p. 81) and that "the day that the youths were relegated to the background are over" (p. 96). Their requests are legitimate which require only political will, sincerity of purpose, recruitment of patriotic personnel and strategically functional policy framework to get them qualitatively implemented. The challenges in the Niger Delta region do not require political gimmicks, empty and bogus promises and unnecessary periodical establishment of commissions but a robust conviction to get thing done.

With sturdy conviction, it is imperative to do away with personnel of questionable character; fraudsters in the gab of statesmanship and mediocre but incorporate in the implementation process, selfless, public-spirited and nationalistic indigenes. Involvement of the indigenes is vital because it is only one that wears the shoes that knows where it pinches.

It is not exaggerative to recommend derivative principles, resource control or fiscal federalism (Akintunde and Hile [10]). This is a sure approach to giving the people quality sense of belonging and curbing the menace of illegal oil thievery (bunkering) and youth restiveness. If done, unnecessary pipe leakages and explosions resulting from illegitimate oil burglary would end or at least curbed to the barest minimum. Derivation principle would include employment of suitably qualified indigenes into strategic "managerial and administrative" (p. 97) positions in the companies. Ejike's *Oil at my Backyard* exemplifies this fact with the emergence of Ngozi, the daughter of the soil, to the political scene, as well as approval of Chris' study leave-with-pay (p. 129) and his later promotion to director in Eluala Oil Company.

Fundamentally, critical, concerted and patriotic efforts need to be made in the cleaning of the environment of oil spillage. Oil spillage is an ecological terrorism which does not require lip service and establishment of toothless and unfunded commissions. It is no doubt costly to clean up spillage. For instance, Ayandale [5] observed that "the resultant environmental degradation from gas flaring, dredging of larger rivers, oil spillage and reclamation of land due to oil and gas extraction across Niger Delta region cost about US$758 million every year". Notable, in "August 2017, Nigeria launched a $1 billion clean up and restoration program" (UN [11]), and "this will last for 30 years" (Vindal [12]). The whopping cost, however, cannot be equated to the huge loss of ecosystem, biodiversity, aquatic lives, human lives and properties. Consideration of the large cost above human life and environmental fecundity amounts to negligence and diversion of government's primary and statutory responsibility of protection of lives and properties and that of oil companies' statutory corporate social responsibility. There should, therefore, be synergy and collaboration between the oil companies and government to urgently achieve it.

Petroleum Industry Act/Bill (PIA/PIB) (RLF [13]) signed into law on 16 August 2021 needs to be implemented immediately. The Act which provides the legal, governance, regulatory and fiscal framework for the Nigerian Petroleum Industry as well as the establishment, and development of host communities and other related matters in the upstream and downstream sectors of petroleum industry has since promulgation in 2021

existed in principle. The repealed extant Petroleum Act (2004) and Associated Gas Reintegration Act (1979) were not broad-based and could not achieve much. It is hopefully optimistic that immediate implementation of PIA would solve most imbroglio experienced in the Niger Delta region.

REFERENCES

[1] Onyema, C., Jnngle and oil green: Currents of environmental discourse in four upland Niger Delta narratives. *From Boom to Doom: Protest and Conflict Resolution in the Literature of Niger Delta*, Springfield Publishers: Owerri, pp. 189–209, 2011.
[2] Wiwa, K., *In the Shadows of a Saint: A Son's Journey to Understanding His Father's Legacy*, Steer Forth Press: Vermont, p. 45, 2001.
[3] Nwahunanya, C., Introduction: From Boom to Doom: The Niger Delta in Contemporary Nigerian Literature. *From Boom to Doom: Protest and Conflict Resolution in the Literature of Niger Delta*, Springfield Publishers: Owerri, pp. iii–xxi, 2011.
[4] Ejike, I., *Oil at my Backyard*, Nation-Wyde Printers: Owerri, 2001.
[5] Ayandale, P., Assessing wetland degradation and loss of ecosystem services in the Niger Delta, Nigeria. www.agris.foa.org/agric-search.
[6] Vindal, J., Nigeria's agony dwarfs the Gulf oil spill: The US and Europe ignore it. www.theguardian.com/world/may. Accessed on: 15 May 2022.
[7] Nwahunanya, C., The lachrymal consciousness in the literature of the Niger Delta: Its implications for conflict resolution. *From Boom to Doom: Protest and Conflict Resolution in the Literature of Niger Delta*, Springfield Publishers: Owerri, pp. 37–48, 2011.
[8] Ibeanu, O., Civil society and conflict management in the Niger Delta: Scoping gap for policy and advocacy. *CLEEN Foundation Monography Series*, No 2. CLEEN Foundation: Lagos, pp. 9–18, 2006.
[9] Ako, R., The struggle for resource control and violence in Niger Delta. *Oil and Insurgency in the Niger Delta: Managing the Complex Politics of Petro-Violence*, eds C. Obi & S.A. Rish, ED Books: New York, pp. 76–83, 2011.
[10] Akintunde, J. & Hile, M., Issues in resolving oil conflict in Niger Delta. *Financial Nigeria*. www.Financialnigeria.com. Accessed on: 15 Jun. 2022.
[11] United Nations (UN), Nigeria launches $1 billion Ogoniland clean-up and restoration programme. www.UN Environment. Accessed on: 10 Jun. 2022.
[12] Vindal, J., Niger Delta oil spills clean-up will take 30 years, says UN. www.theguardian.com/aug/Niger. Accessed on: 10 Jun. 2022.
[13] Resolution Law Firm (RLF), Nigeria: Overview of the New Petroleum Industry Act 2021. www.mondaq.com/Nigeria/overview. Accessed on: 10 Jul. 2022.

SECTION 3
PLANNING FOR RISK, CLIMATE CHANGE AND NATURAL HAZARDS

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MANAGEMENT AND CONTROL TOOL FOR HEALTH EMERGENCIES IN THE URBAN ENVIRONMENT

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ABSTRACT

Recent "health disasters" call for reflection on the reduction of the public health risk brought about by the disaster and the response dispensed to pandemic outbreaks, which have revealed organisational and health gaps including global coordination and mobilisation to the event. It is therefore necessary to provide a response to a pandemic by adapting it to the specific characteristics and needs of a specific territory, preparing targeted actions and interventions to contain possible risks to the population and safeguard the maintenance of general activities and services. The objective of this study is to establish a methodology, incorporating risk reduction and preparedness in the design and planning to increase the resilience of local communities, providing guidelines for the drafting of specific area emergency plans. It is necessary to fully optimise the use in emergencies of the resources present on the territory by putting them into a system with local civil protection organisations and to maximise the use of the various assets in relation to the possible evolution of critical situations, directing the activities of forecasting, prevention, rescue and overcoming assigned to several bodies and structures. This is done by applying an innovative methodology, through the use of BIM, which must compose a database useful both for tactical-operational coordination bodies in intervention activities during the management of a crisis, and in the facility management of settlement assets, helping in the planning of technological/environmental maintenance and management activities. Acquisition and sharing of structured data in order to maximise and make more efficient the smart governance and smart economy process of the city, technologically synthesised in a three-dimensional and interactive image of the urban environment.
Keywords: pandemics, risk, management, tool, health emergency plan, BIM, CIM.

1 INTRODUCTION

Evidence suggests that the likelihood of pandemics has increased significantly due to global integration, urbanisation and changes in land use [1]. Current "health disasters" call for reflection on the risk reduction brought about by disaster and the response dispensed to pandemic outbreaks, which have revealed organisational and health gaps including global coordination and mobilisation for response [2].

Risk reduction is structured through the reduction of the vulnerability of communities affected by a possible pandemic event that exposes them to the possibility of potential dangers not only to public health but would also affect various economic, physical, environmental and social coefficients that are articulated in the community. The latter are dynamic factors that affect the varying susceptibility and sensitivity of an individual, a community, assets or systems to impacts from catastrophic events; elements, such as social inequalities, levels of urbanisation, economic vitality, growth rates, that shape a community's ability to respond to damage.

In the literature of emergencies there are a variety of techniques for examining vulnerability with methods applied in assessment that relate to risk perception and vice versa. Scarce, on the contrary, is the bibliography on vulnerability in health emergencies, i.e. the possibility of potential exposure to dangers: health, economic and social, influenced by different physical, environmental coefficients that are articulated in the community. The latter factors are dynamic, affecting the varying susceptibility and sensitivity of an individual, community, assets or systems to impacts with catastrophic events. Elements, such as social

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inequalities, levels of urbanisation, economic vitality, growth rates, that shape a community's capacity to respond to damage [3]. Thus, vulnerability can be stated in mathematical terms as the product of two factors: susceptibility and susceptibility. Susceptibility is envisaged as the intrinsic aptitude to adapt to variations derived from events, sensitivity on the other hand is understood as the celerity of the mutation through which the equilibrium of the system changes in relation to extraordinary interference.

2 CURRENT CRITICS

Carrying out a study on the Italian territory, hard hit by the Sars COVID-19 pandemic, comparing the various analytical data of recent events, through a global and multi-sectoral approach, serious critical issues emerge. For several years now, social awareness of the increased fragility of the environmental system with respect to the impacts of anthropisation has been acquired and consolidated [4], which would suggest intervening on prevention by building an interdisciplinary strategy between the programming, planning and management tools of the social, territorial and environmental systems [5]. The State-Regions Conference in its session of 25 January 2021 sanctioned the agreement, pursuant to Article 4 of Legislative Decree 28 August 1997, no. 281, between the Government, the Regions and the Autonomous Provinces, on the document "National Strategic – Operational Plan for Influenza Pandemic Preparedness and Response (PanFlu 2021–2023)", following a series of preparatory acts of the procedure leading to the adoption of the plan. The document was published in the Official Gazette No. 23 of 29 January 2021.

This is the tool through which the response to the health emergency in Italy has been based, a guideline for the drafting of regional pandemic plans contextualised to the national pandemic preparedness and response plan. A plan adapted to the specific characteristics and needs through which targeted actions and interventions were prepared, aimed at containing possible risks to the population, useful for safeguarding and maintaining general activities and services. But like the entire multitude of regulations concerning risk, they are characterised by a sectoral approach, by specific relevance to certain phenomena and by a disconnect between processes of territorial government and territorial risk reduction.

The relationship between the concept of sustainability and the government of territorial transformations is increasingly consolidating in contrast to the issues that concern the interpenetration between risk forecasting, prevention and management and the processes that govern a given area. A lack of planning of risk prevention and mitigation interventions and the definition of choices concerning land use planning lead to a series of problems at the emergency management level. Risk mitigation plans and programmes continue to constitute themselves as sectorial instruments capable of affecting planning processes only when they succeed in expressing constraints directly referred to single parts of the territory [6].

A major critical issue is the absence of zoning instruments and organic regulations concerning security in certain districts. The inherent character of a given territory calls for reflection, urban planning disciplines highlight the fact that each territory is an individual, with its own peculiarities and prerogatives that distinguish it as a unicum. The peculiar qualities thus become a characterising factor for the different geographical extensions city, urban area, suburban area, district [7]. In order to optimise the resources of a given territory, to establish rescue actions, to plan containment initiatives for the critical phase, to initiate the transcendence of the emergency and to coordinate the men and means of the local voluntary organisations present on Italian territory. The National Civil Protection Service provides a capillary network system to issue directives and unify the representatives of each operational function of the various levels: the Regional Operations Centre (COR, for emergencies involving several provinces, chaired by the president of the region or his delegate), the Relief

Coordination Centre (CCS, the main body at provincial level and chaired by the prefect or his delegate), the Municipal Operations Centre (COC) and the Mixed Operations Centre (COM, mix operation centre), thus initiating immediate decision-making and collaborative processes.

3 ANALYSIS OF A HEALTH EMERGENCY SITUATION

To better understand the management criticalities of a given territorial system, it was necessary to analyse asset management from the inside. A specific area in central-southern Italy, the Alto Sangro territory, was analysed; in the town of Castel di Sangro, the main municipality in the area, and therefore a reference point for the others, through the activation of the municipal operations centre (C.O.C.), it was possible to plan the organisational and preventive measures to be adopted for the management of the health emergency "covid-19 coronavirus epidemic" which, due to the lack of personnel, funds, structures and means of the smaller municipalities, extended its range of action outside the municipal territory for specific actions. The management of the F1 technical and planning function, through trade union decree no. 29/2020 of the municipality of Castel di Sangro through Law 225/1992 – Art. 15, allowed a process of inspection to highlight and suggest strategic conclusions to support the matter.

The immediate task of applying the aforementioned "Civil Protection Operational Measures for the management of the epidemiological emergency from COVID-19" issued on 3 March 2020 by the Department of Civil Protection of the Presidency of the Council of Ministers indicate the primary and following activities for which the COC is responsible: (a) information to the population; (b) activation of local volunteers, in agreement with the superordinate levels of coordination; (c) organisation of actions at municipal level, in agreement with what has been prepared at regional level, of actions aimed at ensuring the continuity of the supply of essential services, as well as the collection of waste in the areas affected, or that could be affected, by urgent containment measures; (d) organisation of actions at municipal level, in liaison with what has been prepared at regional level, of actions aimed at ensuring the continuity of the supply of essential goods (including fuel supplies) in the areas affected, or that could be affected, by urgent containment measures; (e) planning, or possible activation, of actions to assist the population of the municipalities affected, or that could be affected, by urgent containment measures; (f) planning and organisation of home assistance services for people in home quarantine (e.g. basic necessities, medicines, pre-packaged meals, etc.), possibly carried out by the staff of voluntary organisations, suitably trained and equipped with PPEs.

In the next phase, suitable facilities are identified:

(a) Residential facilities capable of housing COVID-19 patients who do not require hospitalisation, in order to prevent the spread of the infection and enhance the related care setting.
(b) Facilities ready to receive a large flow of people for the diagnosis of COVID-19 positivity, to control transmission; monitor incidence, trends and assess severity over time; mitigate the impact of the virus in health and social care facilities; detect clusters or outbreaks in specific settings; prevent (re)introduction in areas that have achieved sustained control of the virus.
(c) Premises where a territorial vaccination point can be set up, following the indications provided by the National Civil Protection Department with a view to promoting maximum adherence to the COVID-19 vaccination campaign, and respecting the needs of people with disabilities, located in areas that can be easily reached by local public

transport services or provided with ample parking space. All this in order to guarantee a widespread and capillary vaccination system that is necessary to ensure the rapid overcoming of the pandemic situation.

The designated locations for the "drive through" screening campaign have been identified as a number of school complexes and the largest inside the "Teofilo Patini" municipal stadium (Fig. 1), which are functional in the immediate term but lack adequate risk prevention and protection services.

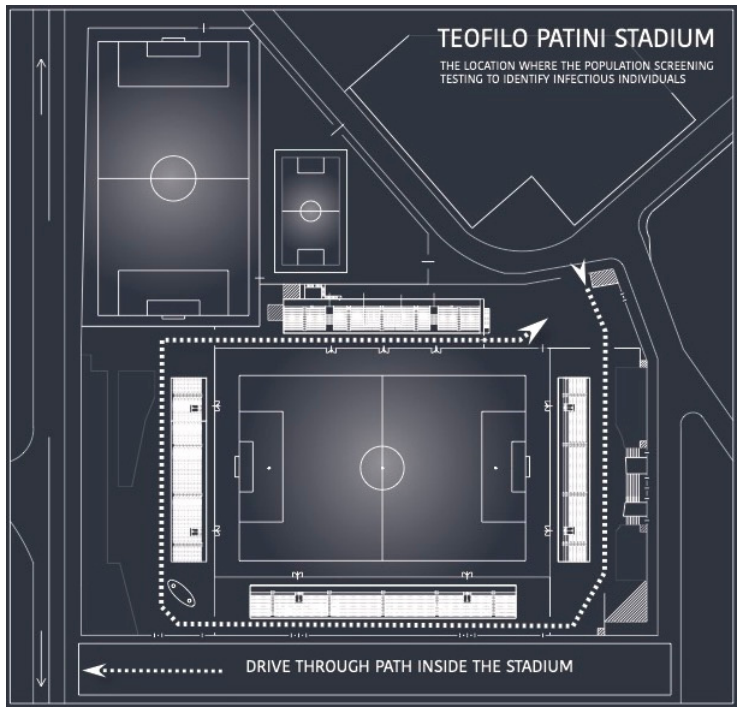

Figure 1: Layout of the location where the population screening testing to infectious individuals.

Prior and proper planning would certainly have entailed a drafting of the Risk Assessment Document (DVR) pursuant to Articles 28 and 29 of Legislative Decree 81/2008 in order to identify risk factors, assess them and understand what measures to adopt for the safety and healthiness of the work environment, in compliance with current legislation. Drawing up preventive regulations to protect users and volunteers by informing them about exposure to risks and measures to contain them.

In view of the high concentration of cars inside the facility, it would have been necessary to assess specific aspects regarding the management of emergencies and fire prevention in sports facilities, as defined in the Decree of the Minister of the Interior of 18 March 1996 and amended by the Ministerial Decree of 6 June 2005, with regard to the organisation and management of emergencies in workplaces.

It is therefore necessary to designate in advance the workers and/or volunteers in charge of implementing fire prevention and fire-fighting measures, evacuation of workplaces in the

event of serious and immediate danger, rescue, first aid and, in any case, emergency management (letter b, paragraph 1, Article 18 of Legislative Decree no. 81/2008); inform all workers who may be exposed to serious and immediate danger of the measures taken and the behaviour to adopt; plan interventions, take measures and give instructions so that workers and/or volunteers, in the event of serious and immediate danger, can cease their activities and move to safety, leaving the workplace immediately; take the necessary measures so that any worker, in the event of danger, can take appropriate measures to avoid the consequences of that danger, taking into account their knowledge and the technical means available; ensuring the presence of extinguishing media appropriate to the class of fire and the level of risk present at the place of activity, also taking into account the particular conditions in which they may be used, an obligation that also applies to fixed, manual or automatic extinguishing equipment, identified in relation to the risk assessment.

A disused public building belonging to a former Mountain Community (local bodies set up between mountain municipalities for the development of mountain areas for the exercise of their own and conferred functions and for the associated exercise of municipal functions) underwent a change of use, without following a precise procedural procedure, and changed into an extraordinary territorial vaccination point.

4 METHODOLOGY

Based on the above, it is necessary to establish a methodology, incorporating risk reduction and preparedness in planning to increase the resilience of local communities. Providing guidelines for the drafting of the emergency plan with a constructive and environmental vision, based on the development of settlement uses, using process innovation and social organisation through the analysis of the transformation processes specific to a place and time, which provide a response to a series of variable needs [8]. This is in order to fully optimise the use in emergencies of the resources on the territory by putting them into a system with the local civil protection organisations and to maximise the use of the various assets in relation to the possible evolution of critical situations, by targeting forecasting, prevention, rescue and overcoming activities assigned to several bodies and structures. In fact, the complexity of the risks requires the coordinated use of all the professional skills and resources available, as established by the regulations in force on the subject (law no. 225 of 24 February 1992); inevitably addressing the issue of emergency planning, which must no longer be of a "compilative" type but a tool for knowledge of the territory, oriented both towards risk reduction and therefore planning, and operational [9] investigating at the same time the lack of connection between "ordinary" and "emergency" planning, which, despite being joint, move on different levels, sometimes presenting considerable distances with respect to common objectives [10].

To address this issue, it is proposed to use a reformatory methodology of the city's asset data acquisition system, i.e. a new working tool for the knowledge and management of both public and private real estate assets.

The representation of urban models is implemented with a geographic information system designed to manage the territory, useful for acquiring, managing, and visualising data acquired from a given land surface in order to elaborate thematic maps that are fundamental for understanding the patterns and relationships between the various elements that make up the system. Through the use of certain software, one is able to manage a myriad of geo-referenced information, related to a tranche of territory, which can be defined in cartogram or schematised in tabular form. This technology has undergone considerable evolution in recent decades, just think of the Google Earth systems and Maps geographic Internet services that allow the search and display of maps through a link of alphanumeric and geometric data

that, through the superimposition of satellite images, constitute a planetary geographic atlas, but this structure does not allow to respond to the complex physical interactions such as human resources, procedures, tools, organisational aspects, complementary to the previous data, it is therefore necessary to resort to Geographical Information Systems [11] that are fundamental for the involvement of the stakeholders in the decision-making processes, defining forecasting activities and intervention options in a smooth way.

In order to channel all these data into a single information system, it is necessary to integrate the system and resort to a process of intelligent digitisation of the environment that involves the Building Information Modelling methodology, which can support the in-depth semantics of urban volumes, infrastructures and other functional parts of the area [12], resorting to a methodology that involves the generation and management of digital representations of the physical and functional characteristics of the building [13]. In order to perfect facility management, a grafting of data is required that generates a rapid consultation and immediate understanding of the mass of data, dissimilar to each other and acquired through different logics, coming from a given area. Taking data concerning buildings as an example: typology, geography, intended use, period of construction, construction materials, plant engineering, flexibility, a timely reading becomes impractical; as in most cases, the data of individual elements are managed within spreadsheets, project reports or in floor plans (paper or digital) without an organised information management system [14]. Research on the 3D moderation of the urban environment has mostly focused on the representation of geometric models but has generally neglected other topological and semantic aspects [15]. Recently, many researchers have paid attention to the development of 3D urban moderation, acting increasingly in certain applications such as urban planning, land-use management and flow studies [16].

This dynamic, implementable and conspicuous data should be channelled into a system, as it defines all the information concerning a characteristic component of a building, infrastructure or other, so as to compose a database useful both for tactical-operational coordination bodies in intervention activities during crisis management, analysing information and thus helping to concert strategic decisions, and in facility management of settlement assets, as well as helping in planning maintenance activities and technological/environmental management.

Acquisition and sharing of structured data with a view to maximising and enhancing the smart governance and economy process of the city, technologically summarised in a three-dimensional and interactive picture of the urban environment, useful in scenario analysis, being concretely a digital cadastre containing a myriad of information of the city, defined as C.I.M. Civil or City Information Modelling, resulting from the integration of BIM, GIS and IoT. Thus, it is possible to move from the simple concepts of GIS and BIM to that of City Information Modelling (CIM) (Fig. 2), which is characterised by a multidisciplinary union of all spatial model data [13]. An innovative system that aims to regulate the entire urban planning process through the application and use of tools applied to the optimisation of procedures, with intrinsic potential that can be extended to various types of emergency plans, not only health.

In Italy, there are types of municipal and inter-municipal emergency plans, consisting of the set of procedures to be implemented in the event of a disaster, in order to guarantee the coordination of the structures, men and means set up to manage the emergency. The essential activities to be carried out are covered, and the main actors operating in the territory and actions to ensure immediate communication to the population are indicated.

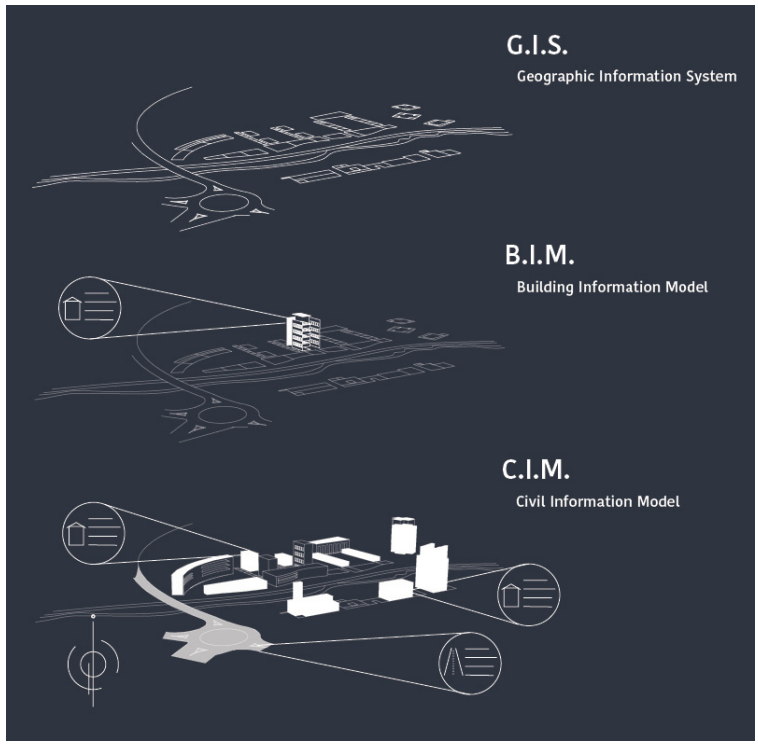

Figure 2: GIS, BIM and CIM, details of the different representations.

Generally, municipal emergency plans are structured in four sections:

1. Territorial framework, i.e. data concerning the settlement and demographic structure: number of residents, with the relative number of people with disabilities and fragility; building and infrastructural heritage, in particular information on strategic and relevant buildings, receptive structures useful for guaranteeing shelter and assistance to the population with reference to the decree of the Head of the Civil Protection Department no. 3685 of 21/10/2003 where the elements of the strategic building and infrastructural heritage are listed: hospitals, schools, universities, rest homes, places of worship, places of mass aggregation (stadiums, cinemas, theatres, shopping centres, etc.), tourist facilities (hotels, resorts, campsites, etc.), assets of artistic and cultural interest, areas of particular environmental interest; sites of Institutional bodies such as the Region, Territorial Government Offices, Town Halls, sites of Operational Structures such as the Fire Brigade, Armed Forces, Police, State Forestry Corps, Red Cross, National Alpine and Speleological Rescue Corps, National sites of Scientific Research (INGV, CNR), sites of voluntary organisations; sites of production activities, industries at risk of major accidents, landfills, hazardous waste disposal plants, plants, depots, storage sites containing radiological material; road and motorway networks, railway networks, railway stations, ports, maritime stations, airports, helicopter landing zones; telecommunications infrastructures; power stations, electricity, gas, water distribution networks; hydraulic works and interventions in progress or planned (embankments, expansion tanks, weirs, etc.); road and railway infrastructure works and crossings

(bridges, overpasses, tunnels, retaining walls). The Civil Protection Department requires the inclusion of this information in the plan, which will make it possible in the emergency phase to have the factors needed to implement the intervention model.
2. Section dedicated to the study of the hazard conditions and risk exposure of the municipal territory in order to define probable scenarios.
3. Operational Procedures i.e. the intervention model to be implemented in the event of an event. With relevant outline indications of the actions to be implemented in the first phase of the emergency.

The parametric model that is suggested to be applied, used to find and survey the urban environment, opens an interoperability between ordinary and emergency planning, opening an interesting link between the urban and building scale using only one software. The data to make up the City information Model from the GIS and BIM environment by integrating can also guarantee coordinated management in the emergency phase.

5 STRATEGY IN HEALTH EMERGENCIES

At present, the pandemic health disaster is not contemplated in the risk scenarios to which a given area is subject, i.e. explanatory documentation, of the possible effects on man, or on the infrastructures present in an area, and any possible description of generic, or particular, events that may affect an area. However, the problems described above highlight the need to prepare and organise a plan that allows a judicious choice of actions to be taken, a health emergency plan applied with CIM methodology would first of all allow the identification of areas and structures necessary to deal with the emergency and increase operational efficiency. Consider the establishment of an extraordinary territorial vaccination point following the organisational and structural guidelines related to the sars-cov-2/covid-19 vaccination campaign, the main functional characteristics and equipment, in terms of furnishings and sanitary material, of the different areas/spaces foresee:

(a) Car park located in the immediate vicinity of the vaccination site, with appropriate signage to guide the flow and behaviour of users, with particular regard to spacing and anti-COVID-19 hygiene rules;
(b) Entrance first area of the premises, in which the user's presence on the appointment list is checked; body temperature is checked; sanitisation is carried out prior to entry; vaccination documentation is handed over, or the correctness and completeness of its compilation is checked, if received in advance of the appointment (with possible support for situations of particular psycho-physical discomfort);
(c) Acceptance, an open space possibly with a suitable view of the other areas of the vaccination site. It is responsible for verifying the user's generalities and acceptance of the completeness of the documentation and its taking over and transfer to the pre-vaccination history collection and clinical assessment area; equipped with a computer workstation, internet access, telephone station;
(d) Anamnesis and pre-vaccinal clinical assessment, in linear sequence with the reception and possibly with a suitable view of the other areas of the vaccination site: technically checks documentation to define suitability for vaccination and the relevant observation time; gives the vaccinee the documentation to be handed over later to the vaccination staff for completion of the relevant fields; equipped with computer workstation, internet access, telephone station;
(e) Waiting area in front of the vaccination lines is dedicated to waiting for the vaccination, with appropriately spaced out and adequate number of seats;

(f) Preparation of vaccine doses, arranged in the immediate vicinity of the vaccine lines, separate from the waiting and observation areas, provides, in accordance with current standards and scientific guidelines: all the useful phases up to the preparation of the individual doses/syringes for each vaccination, using an aseptic technique to guarantee the sterility of each dose; the delivery of the doses/syringes to the various vaccine lines. Equipped with a refrigerator (with ensured electrical continuity where the organisation and the types of vaccine used require it), containers in accordance with the law for special waste and the safety of operators, sanitary material useful for preparing the individual doses/syringes for each individual vaccination;
(g) Administration, consisting of one or more vaccination lines and provides for: receipt of documentation and further verification of correspondence between user and documentation; carrying out the vaccination in accordance with current standards and good practice; accurately informing the user of what to do during the observation time; each vaccination line is equipped with special waste containers, sanitary material useful for vaccination;
(h) Computerised registration of the vaccinated user's data on the vaccination registry portal (or other regional information system in application cooperation) and the printing of the relevant vaccination certificate is preferably carried out by the administrative staff once the vaccination has been administered, at the time of access to the observation area. This does not exclude the possibility of registration at the same time as the vaccination, in particular where there are two operators per vaccination line. In the latter case, if at least one of the two operators is a doctor, the anamnesis, the administration of the vaccine and finally the computer registration can be carried out in sequence. Equipped with a computer workstation, internet access, telephone station;
(i) Observation, separate from the waiting area, facing the vaccination lines and the exit, is used for post-vaccination observation, for a minimum of 15 minutes. It is as close as possible to the medical care area. It is equipped with appropriately spaced seating in a suitable number taking into account the spatial criterion for defining needs (4 sq. m/person);
(j) Medical assistance, a room or space separated from the rest of the areas of the vaccination site, is dedicated to the medical assistance the user may require at any stage of the vaccination process. Where physical space does not allow for wall separation, the use of screens is useful, with the equipment of the area is specified in an annex;
(k) Exit to facilitate the rapid outflow of vaccinated users and any accompanying persons at the end of the observation period, separate from the entrance. Entry/exit routes must be clearly indicated and differentiated, avoiding overlapping. Equipped with containers for general waste.

In addition to descriptive descriptions of specific functional characteristics and personnel, equipment, devices, health care furnishings and drugs.

Foreseeing, planning and identifying a priori strategic buildings suitable for this function is fundamental to avoid unnecessary waste of money by following a circular economy model of production and consumption that implies sharing, lending, reusing, repairing, reconditioning and recycling existing products for as long as possible, without resorting to maxi-projects, as happened, to build 3,000 circular halls investing 8 million euro. This would increase the resilience of an area understood as the system's ability to adapt to conditions altered by disruption and the ability to develop and adopt alternative response strategies.

In the building context, an inability to manage the uncertainties of the changing context, i.e. the fickle environmental requirements and the equally variable requirements of the users

in that context, tends to render the "building system" obsolete and reduce its useful life. Generally by flexibility we mean the ability of a system to be easily modified so as to respond to changes in the context in a timely and convenient manner, then it can be considered in the emergency phase as a benefit for management and operational efficiency and reduces the obsolescence of such buildings guaranteeing their function and increasing the permanence of the system over time. It is necessary to set up a different vision of structures and move from the static dimension (the building as a finished product) to a dynamic and transitory vision of living in a given environment, i.e. the availability of volumes capable of evolving according to the uncertainty and variability of the users [17] (Fig. 3).

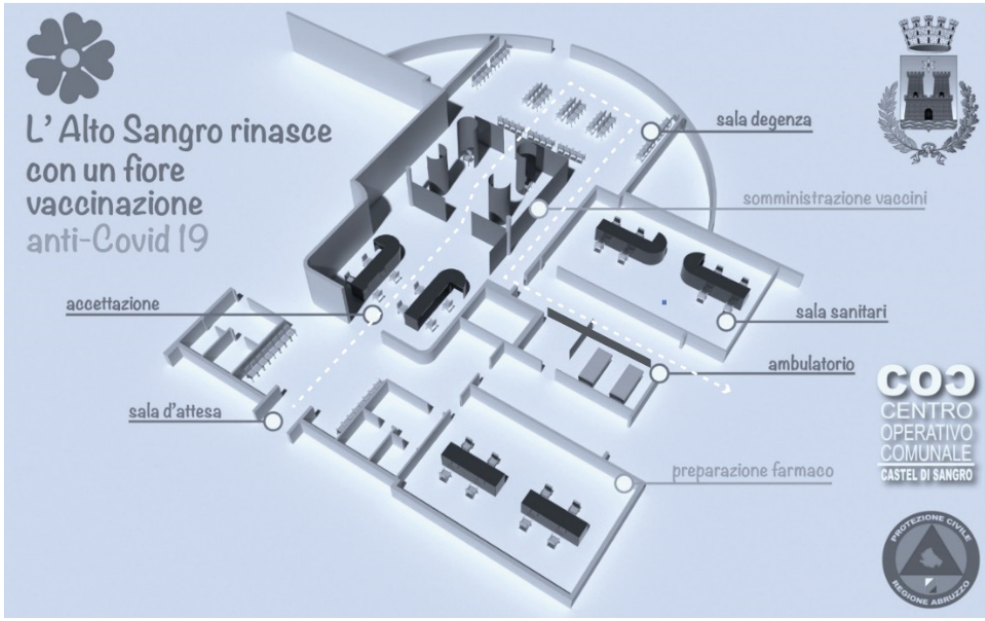

Figure 3: Representation of the extraordinary vaccination centre in the town of Castel di Sangro.

The study aimed at defining the criteria for the implementation of the flexibility of adaptability and changeability is therefore part of the ordinary and emergency planning that can be carried out through the CIM system, which is realised through the property census and three-dimensional BIM modelling of the buildings whose development will have to follow a certain LOD (level of detail and development) that defines the hierarchy of information and priorities of a single element in order to facilitate the reading in the emergency phase such as installations, maintenance, space management, safety, equipment, building geometry, height, construction material; by defining a methodology on which to base the realisation of a three-dimensional urban system, in constant update, it is possible to start a regeneration of an area through facility management as BIM provides opportunities for the management of elements by automatically making available a considerable amount of data giving an account of the real estate and its peculiarities, the number of users of a given building, the cognitive layers on land use, morphology and geology of the soil, thus becoming an indispensable control and coordination system.

REFERENCES

[1] Morse, S.S., Factors in the emergence of infectious diseases. *Emerging Infectious Diseases*, **1**(1), pp. 7–15, 1995.
[2] Pathmanathan, I., O'Connor, K.A., Adams, M.L., Rao C.Y., Kilmarx, P.H., Park, B.J., Mermin, J., Kargbo, B., Wurie, A.H. & Clarke, K.R., Rapid assessment of Ebola infection prevention and control needs: Six districts, Sierra Leone, October 2014. *Morbidity and Mortality Weekly Report,* **63**(49), pp. 1172–1174, 2014.
[3] Cutter, S.L., Vulnerability to environmental hazards, 1996.
[4] Stanganelli, M., La vulnerabilità territoriale ai rischi naturali. *Proceedings of the XXIV Italian Conference on Regional Sciences*, 2004.
[5] Manzo, R., Strumenti e metodi del governo del territorio applicati al tema della pianificazione delle aree a rischio di incidente rilevante, nell'attuazione del D.M. 9 maggio 2001. *Conference Proceedings Risk Assessment and Management in Civil and Industrial Settlements*, 2004.
[6] Ioannilli, M., Sicurezza Territoriale, Governo del Territorio, Protezione Civile.
[7] Francini, M., Palermo, A. & Viapiana, M.F., Il piano di emergenza nell'uso e nella gestione del territorio. Menoni, S., per un approccio territoriale ai piani di emergenza, 2021.
[8] Mangiarotti, A., In nome dell'architettura, 1987.
[9] Di Ludovico, D. & Fabietti, W., Strategic environmental assessment, key issues of its effectiveness. The results of the Speedy Project. *Environmental Impact Assessment Review*, **68**, pp. 9–28, 2017.
[10] Francini, M., Palermo, A. & Viapiana, M.F., Il piano di emergenza nell'uso e nella gestione del territorio. *La gestione delle emergenze e il ruolo della pianificazione: gli strumenti a supporto di una politica territoriale efficiente*, eds A. Marucci, M. Pollino & S. Giovinazzi, Franco Angeli Editore: Milan, 2019.
[11] Bocconcino, M. et al., BIM GIS AR per il facility management, 2015.
[12] Azhar, S., Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering*, pp. 241–252, 2011.
[13] Xu, X., Ding, L., Lou, H. & Ma, L., From building information modeling to city information modeling. *J. Inf. Technol. in Construction*, pp. 292–307, 2014.
[14] Osello, A. et al., BIM GIS AR per il Facility Management, 2015.
[15] Brenner, C. & Haala, N., Fast production of virtual reality city models, 2001.
[16] Benner, J. et al., Flexible generation of semantic 3d building models, 2015.
[17] Cellucci, C. & Di Sivo, M., Habitat contemporaneo. *Flessibilità tecnologica e spaziale*, Franco Angeli Editore, 2015.

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OPTIMISING STAKEHOLDER COOPERATION IN INFRASTRUCTURE DEVELOPMENT

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ABSTRACT

Built projects are levers that drive economic growth. Correspondingly, with the economy under pressure, the need for infrastructure investment in South Africa is more apparent now. Provision of infrastructure has been considered the responsibility of government, with projects often financed by the government, from local to national level and constructed by private contractors – an arm's length relationship. Performance of these projects has been suboptimal. For a long time, the sector has witnessed an increase in the promotion of more cooperation between the public and private sectors in infrastructure development and operation. Public–private partnerships (PPPs) provide alternative ways to involve private sector in more meaningful ways in public infrastructure delivery. PPPs are not only a financing tool in government investment, but an effective project management approach that public and private sectors could employ in developing infrastructure, jointly sharing risks, costs, and resources. However, despite known PPP benefits, there is limited cooperation between the public and the private sector. There remain some reservations with the private sector on how South Africa will fair under the current leadership – leading to the private sector being shy to invest and openly collaborate with government. Partnership arrangements at strategic level are still difficult, failing to instil confidence at a tactical level where projects are controlled. The private sector needs stability in order to feel confident about investing and joining forces with public sector. This paper looks at innovative approaches to improve cooperative partnerships in public infrastructure development.

Keywords: infrastructure, private sector, South Africa, stakeholder cooperation.

1 INTRODUCTION

While investing in mega capital projects brings forth considerable benefits, getting the act right is not always easy. As is normal with infrastructure delivery, mega projects have so many ends to integrate for success. In particular, achieving optimal project delivery requires that the different levels and types of interests as well as the needs of critical stakeholders be looked into, understood, and leveraged. But the construction industry is fragmented and complex [1], eschewing collaboration and strategic vision [2]. The lack of common understanding among various stakeholders in projects is often considered as the primary cause for project failure [3]. To overcome these complexities and challenges, planners and project implementers need to leverage the benefits of multi-stakeholder involvement and their diverse inputs. This paper explores strategic opportunities to optimise stakeholder cooperation in project development for more impactful and resilient infrastructure. It reviews five critical optimization drivers, concluding that, while the key factors are important when considered individually, they are better considered in combination for synergy and improved effectiveness.

2 BACKGROUND

The South African government has, for years, prioritized infrastructure development to stimulate economic recovery and development. Lately, as part of a national economic recovery plan, the government set aside over R790bn for infrastructure in the medium term. In the same vein, the government has set-up several infrastructure development supporting structures such as the Presidential Infrastructure Coordination Committee (PICC),

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Infrastructure South Africa (ISA), and the Infrastructure Fund (IF). The IF is strategically housed within the Development Bank of Southern Africa (DBSA), a development finance institution owned by the South African government. These initiatives are supported by an enabling Act of Parliament, the Infrastructure Development Act (IDA) of 2014 and a National Infrastructure Plan. Government has been actively driving infrastructure investment, hosting investment conferences and seminars, and inviting private sector participation.

Over 2020/2021, South Africa spent over R220bn on infrastructure [4]; this represents a significant portion of the national budget. For more significant impact, infrastructure expenditure should have been more – South Africa is targeting infrastructure spend to be 30% of GDP [5]. These statistics underscore the depth of government's commitment to successful infrastructure delivery and economic recovery. While South Africa has made some tangible progress in providing socio-economic infrastructure, there remain some clear gaps. These gaps indicate that successful infrastructure delivery is not a linear function that solely depends on funding provision. Among other factors, infrastructure delivery depends on the nature or health of the relations and interactions among project implementing partners. Stakeholders pursue influence on projects through their expectation of project value [6]. Partners to an infrastructure development project, both public and private, must cooperate for synergistic benefits. More tangible results can only be realised through constructive public and private sector partnerships. This article explores the opportunities for optimising cooperation between public and private sector players in the infrastructure development arena, with a special focus on South Africa.

3 METHODOLOGY

This research followed a qualitative approach involving desk top literature review for data collection. Data was collected from program progress reports, technical reports and scientific papers and articles. This information was supported and verified through a half-day workshop convened with stakeholders and project partners in the local infrastructure development sector. The data was also analysed qualitatively.

4 SETTING AND CONTEXT

There is a growing narrative underscoring the importance and influence of infrastructure development in driving or catalysing economic growth. Globally, several governments use targeted infrastructure investment and development as props for socio-economic development. This has become common place, particularly in response to economic downturns. However, it has been observed that sheer infrastructure investment is no panacea to economic growth; such initiatives require careful planning and resolve in execution as there are reported high levels of infrastructure projects failure [7]. Some studies estimate project failure to range between 50% and 70% [8]. Research also shows that a high proportion (more than 90%) of public projects suffer from cost escalation and time delays [9]. Thus, careful attention to project detail is required if infrastructure investment is to yield the desired economic growth catalysis.

In light of potential project failure challenges, we suggest that sound partnering of the private and public sectors can help improve project delivery. Several contracting models on the market emphasise increased private sector involvement in public infrastructure projects. This can involve using various forms of partnering. Notably, these contracting models differ from the engineering, procurement, and construction (EPC) model that public projects traditionally use. However, in both the traditional EPC and public–private partnership infrastructure delivery models, success is influenced by, among other things, the quality of

cooperation relationships inherent in the project. The next section briefly outlines common project partnering arrangements.

5 PROJECT DELIVERY PARTNERSHIP OR COOPERATION ARRANGEMENTS

A partnership is an agreement to do something together that will benefit all involved, bringing results that could not be achieved by a partner operating alone and reducing duplication of efforts. A successful partnership enhances the impact and effectiveness of action through combined and more efficient use of resources, shares risks, promotes innovation, and is distinguished by strong commitment from each partner [10].

Several forms of partnerships have emerged over the years. For a long time, public infrastructure has used the engineering, procurement, and construction (EPC) form of contract. The EPC form of contract has defined the nature of relations and cooperation between the public sector/state and the private sector represented by consultants and the contractor. EPC projects consist of the design, procurement, construction, and commissioning of physical assets. Intended to create a clear and objective competitive environment, avoid problems of influence, collusion, corruption and/or bid rigging, the EPC intent is to provide taxpayers with the project at the lowest price that responsible, competitive bidders can offer [11]. In the EPC contracting, assets are transferred to the end-user or owner as a complete functioning unit. Notably, in the EPC model, the public sector purchases assets from the private sector consultants and contractors, with liability limited to asset design and construction, respectively. In the main, financial, and operational risks remain with the public sector. Historically, the majority of infrastructure projects have been implemented using the EPC model, with a significant proportion successfully delivered [12].

Despite widespread use, the EPC form of cooperation has been criticised for being inadequate to ensure successful delivery of projects, resulting, at times, in poor infrastructure delivery performance. Scope, timeline, materials, resource requirements as well as corrupt practices have been considered as key contributors to EPC projects failure [13]. In addition, the balancing of risk between the customer and the contractor is significantly negatively impacting EPC project arrangements. When contract terms are not in place to address uncertainty in duration and cost, there is a fundamental risk imbalance created in these agreements. Each additional level of uncertainty placed upon the contractor comes at a price to the client. In addition, the EPC form of contract is increasingly under pressure from lack of productivity, low or negative profit margins for investors, and the poor adoption of necessary innovations and digitalization [14]. The form of contract has suffered significant deprivation of business and competitiveness – from engineering activities through operations and maintenance to decommissioning. Other criticism of the EPC form of partnership include:

- It is time consuming when savings.
- Suffers from pressures from the low-bid environment, resulting in substantial cost and schedule increases leading to claims, disputes, and costly litigation.
- In order to manage unfair advantage to one contractor, design work is performed without contractor input – therefore missing the opportunity for the contractor to shape and contribute to the design – with practical suggestions and use of construction methods that can add value.
- The contractor's non-involvement in the design contributes to the adversarial nature of the construction process [11].

Over the years, and in response to the shortcomings of the EPC model, alternative contract or partnership or cooperation forms, designed to share risk among partners, have emerged and now exist. These approaches generally work to create a better team approach and to establish an atmosphere of trust – leading to increased innovation to add value and to allocate risk more appropriately [15]. Amongst the alternative contracting forms include PPPs which became more prominent from the 1990s. For these forms of cooperation to work well, constructive relationships between public and private parties are pivotal and should be prioritised. Several types of PPPs are available, each type informed by the risks or responsibilities assigned to the project organisation. Some of these cooperation arrangements include the build, operate and transfer (BTO); build, transfer and operate (BTO); build, own and operate (BOO); design, build, operate, and maintain (DBOM); and, the design, build, finance, and operate (DBFO).

6 PARTNERSHIPS OPTIMISATION OPPORTUNITIES

With the emergence of several partnering arrangements, there exist several optimisation opportunities among stakeholders in infrastructure development. Some of these opportunities are proposed and outlined in the following sections.

6.1 Building of trust among project partners

Trust is an elusive concept. It is defined in several ways by different researchers in different contexts. Trust "involves a recognition of one's vulnerability to the actions and choices of the trustee, involves importantly 'retaining this vulnerability' by not attempting to erect barriers to protect one's interests" [16]. Usually, the interests of partnership members are different, and making oneself vulnerable to others is difficult.

Trust is pivotal in construction partnerships. However, it was observed that the construction industry had been plagued by issues of trust for long, leading the sector to be characterised as having too little trust among partners [17]. Lack of trust usually leads to multiple problems in projects. Trust is crucial in achieving personal and organisational objectives, among people working together. The session learnt that trust is required whenever risk, uncertainty, or interdependence exists – situations that characterise infrastructure projects. As such, trust is important for increasing cooperation between parties to overcome risk and engage in assistive actions in environments characterised by uncertainty. From the above, it is opined that parties to public–private partnerships in infrastructure should invest a lot of energy and resources towards entrenching and building a culture of trust.

6.2 Ensure dedication to common goals

Strong commitment from partnership parties is reflected when partner organisations are equally present and represented by senior and experienced persons who have influence within their parent organisations. Partners must show determination and accept the practicalities of their responsibilities. As noted previously, the objectives and goals of the private and public sectors may not always be well-aligned, with the public sector moved by social service delivery and the private being profit driven. This manifests a chalk and cheese setting. It is essential that synergies and common goals are identified and that these undergird the foundations of the project partnership.

6.3 Ensure strategic fit among partners

The session also underscored the need for public and private partners in an infrastructure project to ensure strategic fit. Strategic fit expresses the degree to which an organisation matches its resources and capabilities with the opportunities in the external environment. In this instance, it implies that both parties match their inherently unique and often different resources and capabilities with their common infrastructure project initiative. This is not an easy assignment to accomplish. The underlying concept of a strategic fit is the achievement of synergies through the use of complementary assets and competencies [18]. In addition, in assessing strategic fit, it is essential for parties to ascertain whether a joint value chain will achieve sustainable advantages for the parties [19]. Key elements to consider when engendering strategic fit include common goals, committed senior management, interdependency, willingness to invest in the relationship, and agreement on joint decision making. In its assessment, supported by submissions from Marshall [20], the session concluded that the notion of strategic fit receives very little attention at the start of the collaborative arrangements in infrastructure projects.

6.4 Delegation of executive power

If infrastructure delivery is to succeed, it is essential that, in all circumstances and at all times, project leadership should be delegated sufficient power to make strategic decisions. This, often, is not the case and failure to do so creates a weak institution, resulting in project leadership always deferring to parent partners for key decisions. This curtails the project organisation's agility, leading to long turnaround times for critical decisions and often project delays. It was agreed that the project organisation should be given executive powers to function and resourced by human capital with the experience and expertise to do so.

6.5 Other optimisation opportunities

Several other key factors for successful infrastructure projects were proposed during the session. Additional key success factors identified in the session include:

- Understanding each other's individual expectations and values.
- Instituting regular and transparent communication.
- Ensuring continuous and transparent communication among stakeholder parties.
- Simplifying and accelerating procurement processes.
- Rationalising project selection processes.

7 CONCLUSIONS

Several partnering arrangements in infrastructure development have emerged over the years. Each of these arrangements have their strengths and weaknesses, with project clients having to select the best possible option. This article contends and concludes that there are tangible possibilities to optimise existing partnering arrangements to best implement infrastructure development. The optimisation opportunities have been well articulated in this paper. It is important to note that, while these key success factors are important when considered individually, they are better considered in combination for improved efficacy. Joint consideration of these partnership optimisation brings to the fore more synergistic value-addition to stakeholder interaction in infrastructure development.

REFERENCES

[1] Curran, M., Spillane, J. & Clarke-Hagan, D., External stakeholders in urban construction development projects: who are they and how are they engaged? *Proceeding of the 34th Annual ARCOM Conference*, 3–5 Sep., Belfast, UK, Association of Researchers in Construction Management, pp. 139–148, 2018.

[2] Alwan, Z., Jones, P. & Holgate, P., Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using building information modelling. *Journal of Cleaner Production*, **140**, pp. 349–358, 2017.

[3] Soon, K.L. & Yang, J., Understanding the need of project stakeholders for improving sustainability outcomes in infrastructure projects, 2021. https://www.irbnet.de/daten/iconda/CIB9838.pdf. Accessed on: 17 Aug. 2022.

[4] Bulbia, T., Government commits to improving infrastructure spending. *Engineering News*, 2021.

[5] NPC, National Development Plan 2030. Our future: Make it work. National Planning Commission: Pretoria, 2012.

[6] Vuorinen, L. & Martinsuo, M., Value-oriented stakeholder influence on infrastructure projects. *International Journal of Project Management*, **37**(5), pp. 750–766, 2019.

[7] Flyvbjerg, B., Over budget, over time, over and over again managing major projects. *The Oxford Handbook of Project Management*, eds Morris, P.W.G., Pinto, J.K. & Soderland, J., pp. 321–344, 2011.

[8] Jenner, S., Why do projects "fail" and more to the point what can we do about it? The case for disciplined, "fast and frugal" decision-making. *PM World Journal*, **IV**(III), 2015.

[9] Koppenjan, J., Veeneman, W., Van der Voort, H., Ten Heuvelhof, E. & Leijten, M., Competing management approaches in large engineering projects: The Dutch RandstadRail project. *International Journal of Project Management*, **29**, pp. 740–750, 2011.

[10] OECD, Successful partnerships: A guide, 2006. www.oecd.org/cfe/leed/forum/partnerships.

[11] Reilly, J., Alternative contracting and delivery methods, 2011. https://www.tunneltalk.com/Contracting-methods-Sep11-Traditional-verus-new-contracting-methods.php. Accessed on: 24 Mar. 2022.

[12] Ke, H., Cui, Z., Govindan, K. & Zavadska, E.K., The impact of contractual governance and trust on EPC projects in construction supply chain performance. *Inzinerine Ekonomika-Engineering Economics,* **26**(4), pp. 349–363, 2015.

[13] Martin, T. & Macleod, I.A., The Tay Rail Bridge disaster revisited. *Proc. ICE, Bridge Engineering*, **157**(4), pp. 187–192, 2004.

[14] Wagner, R.F., EPC 4.0: The quest for reducing CAPEX in EPC projects. *Organization, Technology and Management in Construction*, **11**, pp. 2245–2255, 2020.

[15] Chambley, P.J., Bassford, C. & Tindall, S., The project team approach to the management of risk for a major tunnelling contract at Kingston upon Hull. *American Underground Construction Association News*, **15**(3), 2000.

[16] Brien, A., Professional ethics and the culture of trust. *Journal of Business Ethics*, **4**, pp. 391–409, 1998.

[17] Munns, A.K. & Bjeirmi, B.F., The role of project management in achieving project success. *International Journal of Project Management*, **14**, pp. 81–87, 1996.

[18] Geringer, J.M., Strategic determinants of partner selection criteria in international joint ventures. *Journal of International Business Studies*, pp. 41–62, 1991.

[19] Child, J., Faulker, D. & Stephen, T., *Cooperative Strategy*, Oxford University Press: Oxford, 2005.
[20] Marshall, T., The re-timing of English regional planning. *Town Planning Review,* **73**(2), pp. 171–195, 2002.

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NEW GREEN INFRASTRUCTURE FOR EUROPEAN CITIES: MULTIPLE WAYS FOR IMPROVEMENT AND CLIMATE CHANGE ADAPTATION

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ABSTRACT
The establishment and improvement of nature-based solutions (NBS) to reduce impacts by climate change and improve air quality are a challenging task for urban planning and management. Despite the great interest and willingness to improve the situation, many concerns and questions arise when planning details for the implementation of NBS and green infrastructure. For example, to what extent can improvements be achieved with regard to microdust? Which green infrastructure brings the greatest particulate reduction or greatest temperature reductions for hot summer days? This paper investigates which NBS can be applied in European cities for which purpose based on current scientific literature. Based on an extended literature review the paper gives an overview and illustrates to what extent implemented NBS currently may contribute to tackling challenges regarding climate change. Against this background the paper gives recommendations for urban planning and development under conditions of climate change.
Keywords: nature-based solutions, urban green infrastructure, climate change adaptation, sustainable urban development.

1 INTRODUCTION

Many European cities are seeking to improve their urban environments as a mean to address climate change mitigation and adaptation while simultaneously improving quality of life for their residents through green infrastructure and nature-based solutions (NBS). The European Commission defines green infrastructure as a "strategically planned network of natural and semi-natural areas" aiming to deliver ecosystem services like water purification, air quality, climate change mitigation and adaptation and space for recreation [1]. While the European Commission locates the backbone of green infrastructure in the Natura 2000 network of protected nature areas [1], the World Green Infrastructure Network points out the importance and necessity of green infrastructure in cites for sustainable urban development [2]. NBS, as a part of green infrastructure, are solutions inspired and supported by nature. By utilizing nature and natural features and processes as a response to challenges, they are an addition or replacement to purely technical solutions, adding further ecological, economic and social values by their multifunctional traits [3].

Local governments can chose from a variety of tools and instruments to implement urban green infrastructure: For example, Belfast (Northern Ireland) is working on planting one million trees by 2035 to gain multiple benefits like reduction of carbon and flooding, improvement of air quality and urban cooling, as well as supporting biodiversity and improving the physical and mental health and wellbeing of its citizens [4]. The City of Stuttgart (Germany) installs ventilation corridors and green–blue infrastructure to reduce extreme temperatures and improve the air quality [5]. Bratislava (Slovakia) is investing in

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tree planting, green roofs and rainwater retention facilities to mitigate intense rainfalls and heat through the project "Bratislava is preparing for climate change" [6]. Maribor (Slovenia) has developed a "Strategy for the transition to circular economy in the municipality of Maribor" [7], which includes the regeneration of degraded areas through the implementation of blue and green infrastructures and natural solutions. Budapest (Hungary) promotes NBS in several strategic documents to improve the environment, sustainability and quality of life in the city. Furthermore, Budapest is implementing several projects to bring more green into the city and tackle challenges regarding climate change issues [8]. Transitioning to greener urban environments has been gaining political interest, so it comes as no surprise that the "EU Mission: Adaptation to Climate Change" has been showing interest in possible avenues to assist in greening cities [9]. Although interventions through NBS bring many benefits to both the city climate and the citizens' quality of life and well-being, they need to be carefully planned in order to realize their full potential. Questions concerning land competition, refinancing and the desired type of green structures dominate the discussion between urban stakeholders. As listed in the examples above, NBS are applied for a broad field of targets and goals, since they cover a wide spectrum of interventions. For this reason, cities need to know where, what size and what purpose the implemented green infrastructure need to fulfill to address their specific needs and choose the option which will truly achieve the desired outcome.

2 NBS ADDRESS CURRENT URBAN ISSUES

Current literature on the implementation of NBS for climate change mitigation, identifies several prominent issues these measures are meant to solve. The discussions focus on temperature reduction, air quality issues such as the reduction of microdust [10]–[13] and nitrogen oxides [14], [15], or the crucial role of urban green spaces and green infrastructure for biodiversity [16]. Li and Wang [17] summarized benefits of urban greening for carbon emissions. They point out that the biogenic CO_2 from urban greening spaces should be neglected. The carbon sequestration by urban vegetation (lawns, parks, and residential gardens) can partially offset vehicular CO_2 emission for example. Some densely vegetated areas can even achieve carbon neutrality during warm months due to active plant CO_2 uptake.

With climate change and increased sealing in cities, urban microclimates have shown increasing temperatures in the form of heatwaves and tropical nights and the effects of urban heat islands for citizens and urban environments have been growing [18]. These issues have negative effects on human health and well-being [19]. Temperature reduction is thus an increasing concern of public health and, therefore, local governments are interested in addressing the issue for their residents. Similarly, microdust and NO_2 are also matters of public health, as high pollution levels lead to increased cardio-vascular disease and decrease life expectancy [20]. Biodiversity loss has been a worldwide issue, but growing urbanism in its current form can pose irreversible damage [21]. As cities expand and are facing growing sealing and construction, expertise on local biodiversity and cooperation between local institutions are needed to develop public space in a manner which will integrate the needs of nature to ensure ecosystem services are upheld [22].

The examples mentioned in the introduction illustrate that there is a general interest and willingness to increase and upgrade urban green infrastructure at both local and international levels. However, many concerns and questions arise when planning the details for implementation. For example, to what extent can improvements be achieved with regard to microdust, which green infrastructure brings the greatest particulate reduction or greatest temperature reductions for hot summer days? The paper at hand investigates which NBS can be applied in European Cities for which purpose based on current scientific literature. We

will give an overview and illustrate to what extend implemented NBS currently may contribute to tackling challenges regarding climate change. Against this background the paper gives recommendations for urban planning and development under conditions of climate change. Therefore, the main aim of the paper is:

- to analyze and quantify possible improvements by NBS,
- to summarize recommendations for urban planning, and
- to discuss further challenges in this context.

3 METHODOLOGICAL APPROACH

To get an overview on the development of scientific literature on nature-based solutions and their effects on the urban environmental conditions a literature review was carried out, focusing on the last decade. Specific focus was laid on methodological settings and measurement methods used in relation to NBS. Following keywords were used for the search: Nature based solutions, NBS, green infrastructure, urban, cities, NO_2, NOx, temperature, temperature reduction, microdust, microdust reduction, particulate matter, PM, biodiversity, air quality, city trees, street greening, rain garden, participation, barriers, choice experiment, waste bin charges. The main literature search engines were BOKU:LITsearch (Search Engine of the University of Natural Resources and Life Sciences, Vienna) and Scopus. Case Studies were retrieved in English and German. They were categorized using a table to summarize the main results of each. Studies from non-European countries (e.g. India, Australia, USA) were also taken into consideration. These studies often show a similar improvement of environmental conditions through vegetation in comparison to studies from Europe. However, these studies were not listed in the tables found in the results because of differences in climate and applicable plant species in European cities.

4 RESULTS

Over the past decades an increased interest in the topic green infrastructure and nature-based solution in scientific research and literature can be observed. For the paper at hand, 77 case studies have been investigated from across the globe. It has been found that the distribution of urban issues which address applied NBS and their achieved results are not equally distributed regionally. Some of the urban issues are found predominantly in certain regions of the world: e.g. many southern European countries focus on heat stress, while Asian cities (such as Hong Kong and Shanghai) were found to address issues of air quality, microdust and air pollution more frequently. In the following we present the findings on European case studies.

4.1 Temperature reduction

The studies showed different approaches to measure temperature differences due to vegetation (Table 1). Most commonly the method applied was to conduct the measurement of air temperature at a certain height and also the measurement of surface temperature differences [23]–[25]. These studies investigated surface temperatures in summer between areas exposed fully to the sun and ones located in the shade, or differences between surfaces e.g. asphalt versus grass. All of these studies showed that NBS are able to significantly reduce temperatures in cities. However, the size of the green area, the respective surrounding infrastructure and the type of vegetation are crucial for the overall effectiveness. Rink and Schmidt [26] showed that the cooling effects of urban forests can extend up to 400 m into the surrounding urban area. Smaller NBS such as singular trees were measured only on site and

Table 1: Literature on temperature reduction.

Study	Main issue	Methodological approach	Results	Study area	Recommendations
Georgi and Dimitriou [29]	Improvement of microclimatic conditions through trees	Daily measurements over 16 days	Temperature under the trees of different species decreases with the increase of evaporation, mean reduction of 3.1°C	Chania-Crete, Greece	The choice of species should reflect the local requirements (aesthetics, functional, ecological, and bioclimatic)
Alavipanah et al. [24]	Influence of vegetation cover on land surface temperature	Remote sensing and land use/land cover data to assess the cooling effect of varying urban vegetation cover	Greatest cooling is achieved in grids with a vegetation cover of 70–79%	Munich, Germany	Since location of urban vegetation and its distance to built-up areas play an important role for cooling strategic planning is crucial
Lindén et al. [28]	Microclimate cooling induced by trees	Climate sensors	Maximum difference of 3.9 K was measured between park and street sites	Mainz, Germany	Carefully consider how surrounding geometry may impact variations of the cooling effect
Rahman et al. [25]	Comparing transpirational and shading effects of two urban tree species	Sensors/on site measurements	Linear regression indicated a decrease of 3°C with every unit of leaf area index for grass surface, but 6°C for asphalt surface	Munich, Germany	Species with higher canopy density can be preferred over asphalt surfaces, but species with lower canopy density and low water use can be preferred over grass surfaces
Speak et al. [23]	Reduction of summer surface temperatures by trees	Thermal images were taken at 1 m height pointing to the ground with a thermal camera on eight clear, sunny days with low winds	Mean cooling of 16.4°C for asphalt, 12.9°C for porphyry and 8.5°C for grass	Bolzano, Italy	Trees with a broad canopy and high leaf area index are recommended, since the study suggested that tree height is not as important as crown width for cooling

Table 1: Continued.

Study	Main issue	Methodological approach	Results	Study area	Recommendations
Rink and Schmidt [26]	Urban forests and their influence on urban climate and recreation	The influence on temperature development was investigated through measurements by specially established climate station as well as mobile measurement tours	Temperature inside the urban forest up to 5–6 K lower than in the city center, cooling effects can extend up to 400m into the surrounding urban area	Leipzig, Germany	Urban forests are recommended for shrinking or shrunken cities, and also to revitalize brownfield sites
Lehnert et al. [27]	Effects on thermal comfort by blue and green features in city centers	On-site measurements	Cooling effect of trees from 5.5 to 8.5°C, cooling effect of low vegetation (largely lawns) was 0.9°C on average, similar for fountains	Brno, Olomouc, Ostrava and Plzeň, Czech Republic	Trees have significant influence on reducing heat stress in urban centers, blue features may have an influence on the psychological component of thermal comfort
Kraemer and Kabisch [30]	Air temperature regulation under condition of drought and summer heat	Temperature loggers on-site and high-resolution remote sensing	Cooling by urban green spaces compared to built-up surroundings was approximately 1°C	Leipzig, Germany	Emphasize the need for larger green spaces, complemented by well-distributed small-scale green infrastructure

achieved temperature reductions between 3°C and 8.5°C [25], [27]–[29]. These studies did not investigate changes in temperature to surrounding areas. Two studies focused on changes in surface temperature. One of these, found very high temperature reductions between trees and asphalt (16.4°C) but also between trees and grass (8.5°C) [23]. For greatest cooling, areas with 70–79% vegetation cover were determined to be most effective [24].

4.2 Microdust reduction

Measurement methods for microdust (also known as particulate matter (PM)) reduction through NBS vary a lot depending on the hypothesis for each study. Some use sensors for air quality before and after the implementation of NBS. For hedge rows near streets the measurement of PM levels on both the roadside and behind the hedge is reported [11], [13]. Other studies, focusing on the removal capacities of different species also use air quality sensors, but since they are often interested in the correlation of leaf traits and removal efficiency, often leaf samples are prepared with vacuum filtration, leaching or with microscopic imaging techniques [12], [31].

Different results regarding leaf traits and their particulate matter removal efficiency can also be based on different measurement methods [31]. Besides PM levels in the air and the selection of plants, many studies show that wind conditions play a major role for microdust reduction and deposition [32]. Therefore, aspects of design and layout of open spaces and streets need to be taken into consideration. Evergreens [10], [33] and meadows [12] were found to be more effective in microdust reduction compared to deciduous species and lawns. Kumar et al. [13] state that concerning roadside microdust reduction a height of 1.7 m is required and other authors add that plant species [31] and vegetation cycle [11] must be considered. As shown by the studies in Table 2, NBS reduce microdust, however, factors such as size, type and vegetation cycle will influence the results achieved during measurement.

4.3 NO_2 reduction

NO_2 reduction through vegetation is often investigated using computer models based on on-site measurements, or validated with on-site samples. Only studies, which are based on measurements in the study area and did not use computer models are listed in Table 3.

Since traffic is a main cause for gaseous air pollution, new technologies can affect air quality in different ways, meaning that the possible reduction is often not consistent for different pollution [32]. As with microdust, leaf emergence [15] or type of plant [14] will influence the reduction of pollution and air quality changes. Recommendations for NO_2 reduction in combination with NBS state that further measurements are needed in varying climates and environments [14]. A further suggestion includes separating people from the source of the pollution in measures which encourage greater green infrastructure application [15]. The results of Table 3 indicate the NO_2 reduction is linked to leaf traits and performance of plant species chosen for the NBS.

5 DISCUSSION

5.1 Transferability of the results and related recommendations

The results in Tables 1–3 have shown that NBS influence temperature, microdust and NO_2 in many ways. However, the transferability of the presented results are limited and require a

Table 2: Literature on microdust reduction.

Study	Main issue	Methodological approach	Results	Study area	Recommendations
Bottalico et al. [10]	Air pollution removal by green infrastructure and urban forests	Computer modelling and sensors	Annual pollution removal for PM_{10} by urban forests: coniferous 0.0204 tons/ha, deciduous broadleaved 0.0152 tons/ha, evergreen broadleaved 0.0176 tons/ha, mixed broadleaved and coniferous 0.0247 tons/ha	Florence, Italy	The role of urban forests for air quality improvement has to be assessed together with other positive effects on human well-being
Marando et al. [33]	Seasonal particulate matter (PM_{10}) removal capacity of evergreen and deciduous species	Remote sensing and GIS	Annual PM_{10} removal efficiency is 20–27% higher for evergreen species compared to deciduous broadleaved, PM_{10} removal for deciduous broadleaves is higher in the vegetation period	Rome, Italy	Urban development strategies should be enhancing the natural and artificial green infrastructure network
Sgrigna et al. [31]	Particulate matter capture efficiency of twelve tree species	Vacuum filtration and scanning electron microscopy imaging	Combination of different micro and macromorphological traits is a key factor to enhance PM capture	Terni, Italy	An Accumulation index based on micro and macromorphologies and the PM_{10} load for 12 tree species is presented
Ottosen and Kumar [11]	Influence of vegetation cycle on air pollution by roadside hedge	Air quality monitors on both sides of the hedge	PM reduction up to 52% after the green-up	Guildford, UK	–
Przybysz et al. [12]	Particulate matter accumulation by urban meadows	Plant material samples and sensors	Urban meadows accumulate more PM than lawns, produced biomass and canopy structure seem to influence the capacity	Warsaw, Poland	When planning species compositions to reduce PM pollution, plants with different development cycles are worth consideration
Kumar et al. [13]	Effects of roadside hedges on horizontal and vertical distribution of air pollutants	Sensors on both sides of the hedge	Maximum reduction of PM_1 (−19%), $PM_{2.5}$ (−18%) and PM10 (−17%) at 1 m height	London, UK	Green infrastructure can reduce traffic-related pollution up to 1.7 m height next to a road

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Table 3: Literature on NO_2 reduction.

Study	Main issue	Methodological approach	Results	Study area	Recommendations
Fantozzi et al. [14]	Ozone and nitrogen dioxide concentrations under urban trees	Passive samplers 2 m above the ground	Holm oak trees decrease the NO_2 pollution in all seasons	Siena, Italy	Further measurements in a variety of climatic and environmental conditions to assess the effective role in air pollution removal
García-Gómez et al. [34]	Atmospheric pollutants in peri-urban forests	Air pollution monitoring during 2 years using passive samplers	NO_2 reduction below-canopy ranged from 0 to 41%	Near Barcelona, Madrid and Pamplona, Spain	Because of the high variability found across sites and seasons, environmental factors involved in air pollution removal must be considered
Klingberg et al. [15]	Influence of urban vegetation on air pollution	Measurements 2.5 m above the ground with passive diffusion samplers	NO_2 reduction of up to 25% after leaf emergence	Gothenburg, Sweden	Pollutant exposure for people can be reduced by separating people from traffic, promoting urban green spaces

careful consideration by urban planning. For example, the effects on microdust reduction are only relevant, if the green infrastructure protects areas for pedestrians. While local government and policies speak about city wide targets, the effects are often only measured in the direct surroundings of the implemented NBS [11], [13]–[15], [23], [25], [27]. Furthermore, several authors [11], [25], [27], [31] base their findings on specific plant species and recognize that different plant types and their growth development will influence the results. Those responsible for implementing NBS must consider that they cannot copy what other cities have done or base their decisions on aesthetics only. This also connects to the recommendations of the Global Assessment Report on Biodiversity [21]. Expertise is needed to decide which tailored solutions will reflect not only their urban development strategy targets but also climate and plant species that can flourish in the given environment. NBS can provide multifunctional solutions to climate adaptation issues, if planners connect their selection of NBS with the variety of ecosystem services they can provide based on correct selection of plant species. To achieve the greatest possible effect, main goals to pursue and other framework conditions to be complied with must be defined. Based on this, plant species, suitable locations and the size of the measure can be defined. Possible interactions, constraints and obstacles already common must be considered in the implementation of new NBS from early planning stages. The presented results should encourage cities to connect with experts to find tailored solutions based on NBS and to strengthen the collaboration between city's officials and other local actors to ensure the suitability of the NBS [35]. The EU would be in a position to use financial and policy instruments to assist (local) governments in this regard, as they are already encouraging member states to apply NBS as indicated in policy documents and project funding [3], [9].

5.2 Additional factors influencing the planning of green and blue infrastructure

The literature review also reveals that three additional factors influence the capacity and effectiveness of NBS in urban planning: financial resources, biodiversity enhancement and the consideration of design and usability of green spaces for the local urban population.

Beside the costs for planning and implementation, the ongoing maintenance costs (maintenance, replacement plantings, etc.) must also be considered. The presented findings, e.g. by Horváthová et al. [36], show that the transformation from lawn to meadows will contribute to significant temperature reduction, in addition the adapted management will increase the cost efficacy [36], [37]. Here again, the tailored selection of NBS will greatly influence infrastructure investments and maintenance costs. In addition to material investments, human capital costs must also be considered from early stages of the planning process for participation, workshops or programs for schools or kindergartens. The costs for personnel and materials must be calculated here. Financial resources for monitoring, evaluation and modifications should be planned for sustainable NBS performance (e.g. may be necessary to use different plant species due to climate change or other environmental factors).

The role of biodiversity and its positive effects on the urban environment is another important point in favor of creating new green spaces. Studies show that biodiversity is perceived and valued by residents [38]. In connection with this, there are not only opportunities for people to perceive nature and an improvement in well-being, but also improve climate change adaptation in urban environments [39]. A contribution to climate change mitigation can be made if carbon sequestration takes place through NBS. In Leipzig, Germany, an urban forest was planted on brownfields resulting from urban shrinking [26].

In addition to the efficiency of individual measures described above, cities must also consider design and the usability of the facilities. Here, there is a need for social science research to determine residents' preferences. Cultural differences in how space is used or aesthetics for example will influence which NBS are accepted and which are not. Culture can also influence the interest in participation or engagement and sense of community [40], [41] and ownership of public space [42]. Recent research confirms this additional requirement focusing on participation [38], just distribution [43], a right to participate in design processes and possibilities to take action. Since the beginning of the COVID-19 pandemic, these social issues have also been gaining prominence and been increasingly included in discussions on what NBS can add to urban environments [44].

5.3 Recommendation for further research

To enhance the comparability across NBS and between urban environmental conditions we propose to standardize the methodological approaches and measurements. Current research states a lack of high-quality sensing systems and expertise within the cities beside the difficulties in financing a suitable infrastructure and an adequate monitoring systems [30]. A further standardization of NBS related research will also help to enhance the transferability and strengthen the societal and political valuation of NBS. Further research findings are needed to transfer these case study findings into detailed planning guidelines. This research has to address the complex urban climate, wind directions and speed, orientation of building and street canyons, barriers, turbulences etc. which influence both air exchange and transportation and deposition [11], [13], [15], [23], [45]. Still, few studies have investigated how big NBS need to be in order to reach certain goals for the temperature reduction and air quality improvement. These research gaps must be filled in order to implement NBS efficiently and effectively.

Finally, we see a need for an integrated research equally considering ecological, economic and social aspects related to NBS. Badura et al. [38] used a survey and choice experiment to investigate the preferences and valuation of citizens in the city of Prague. They found that respondents in general support the implementation of NBS, the support was even greater if they already had negative experiences with heat waves, which was reflected in their willingness to pay for NBS. According to the survey, the citizens value measures which support biodiversity and they prefer implementation of NBS in public spaces rather than on public buildings. Applying a choice experiment across a variety of cities would give greater insight into preferences of citizens in different regions and across cultures. Such a study would benefit urban planners and governments who must consider not only technical but also social aspects of NBS and green infrastructure construction.

6 CONCLUSION

The paper at hand illustrates the significant improvements for urban environments by NBS. It is of great importance to protect residents by avoiding further air pollution from traffic and reducing emissions and temperatures of urban heat islands. However, additional studies are needed to verify results from the presented case studies and related model calculations in real-world conditions. As planning is carried out for the benefit of residents and land use competition between different uses is already pronounced, social concerns must be increasingly integrated into political decisions in the future in order to secure the quality of life in cities in the long term. Therefore, further research is needed to understand the trade-offs between different improvements by NBS such as microdust reduction or temperature reduction not only from a purely technical perspective but also from a social science

perspective. Overall the possible contributions by NBS need to be planned considering the contribution to climate change and human health, in the context of economic possibilities, biodiversity enhancement, social and societal needs in an integrated manner.

REFERENCES

[1] European Commission, The forms and functions of green infrastructure. https://ec.europa.eu/environment/nature/ecosystems/benefits/index_en.htm.

[2] World Green Infrastructure Network, Key definition: Green infrastructure, 2021. https://worldgreeninfrastructurenetwork.org/key-definition-green-infrastructure/.

[3] European Commission, Nature-based solutions, 2022. https://ec.europa.eu/info/research-and-innovation/research-area/environment/nature-based-solutions_en. Accessed on: 28 Jul. 2022.

[4] Belfast City Council, Resilient Belfast one million trees, 2021. https://www.belfastcity.gov.uk/onemilliontrees.

[5] Landeshauptstadt Stuttgart, Klimawandel. https://www.stuttgart.de/leben/umwelt/klima/klimawandel/.

[6] Capital City Bratislava, Bratislava is preparing for climate change: The pilot application of measures in sustainable rainwater management in an urbanized environment, 2021. https://bratislavazelenajsa.sk/about-the-project/?lang=en.

[7] Wcycle Institute Maribor, Strategy for the transition to circular economy in the municipality of Maribor, 2018. https://www.greencycle.si/static/strategy.pdf.

[8] Oppla, Budapest: NBS for climate resilience and pollution control, 2022. https://oppla.eu/budapest-nbs-climate-resilience-and-pollution-control.

[9] European Commission, EU mission: Adaptation to climate change. https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/adaptation-climate-change-including-societal-transformation_en.

[10] Bottalico, F. et al., Air pollution removal by green infrastructures and urban forests in the city of Florence. *Agriculture and Agricultural Science Procedia*, **8**, pp. 243–251, 2016. DOI: 10.1016/j.aaspro.2016.02.099.

[11] Ottosen, T.-B. & Kumar, P., The influence of the vegetation cycle on the mitigation of air pollution by a deciduous roadside hedge. *Sustainable Cities and Society*, **53**, 101919, 2020. DOI: 10.1016/j.scs.2019.101919.

[12] Przybysz, A. et al., Where trees cannot grow: Particulate matter accumulation by urban meadows. *Science of the Total Environment*, **785**, 147310, 2021. DOI: 10.1016/j.scitotenv.2021.147310.

[13] Kumar, P. et al., Understanding the effects of roadside hedges on the horizontal and vertical distributions of air pollutants in street canyons. *Environment International*, **158**, 106883, 2022. DOI: 10.1016/j.envint.2021.106883.

[14] Fantozzi, F. et al., Spatio-temporal variations of ozone and nitrogen dioxide concentrations under urban trees and in a nearby open area. *Urban Climate*, **12**, pp.. 119–127, 2015. DOI: 10.1016/j.uclim.2015.02.001.

[15] Klingberg, J. et al., Influence of urban vegetation on air pollution and noise exposure: A case study in Gothenburg, Sweden. *Science of the Total Environment*, **599–600**, pp. 1728–1739, 2017. DOI: 10.1016/j.scitotenv.2017.05.051.

[16] Filazzola, A., Shrestha, N. & MacIvor, J.S., The contribution of constructed green infrastructure to urban biodiversity: A synthesis and meta-analysis. *Journal of Applied Ecology,* **56**(9), pp. 2131–214, 2019. DOI: 10.1111/1365-2664.13475.

[17] Li, P. & Wang, Z.-H., Environmental co-benefits of urban greening for mitigating heat and carbon emissions. *Journal of Environmental Management*, **293**, 112963, 2021. DOI: 10.1016/j.jenvman.2021.112963.
[18] Ward, K. et al., Heat waves and urban heat islands in Europe: A review of relevant drivers. *Science of the Total Environment*, **569–570**, pp. 527–539, 2016. DOI: 10.1016/j.scitotenv.2016.06.119.
[19] Scherer, D., Fehrenbach, U. & Lakes, T., *Quantification of Heat-Stress Related Mortality Hazard, Vulnerability and Risk in Berlin, Germany*, Gesellschaft für Erdkunde zu Berlin, p. 144, 2014.
[20] Lelieveld, J. et al., Loss of life expectancy from air pollution compared to other risk factors: A worldwide perspective. *Cardiovascular Research*, **116**(11), pp. 1910–1917, 2020. DOI: 10.1093/cvr/cvaa025.
[21] IPBES, Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019.
[22] Schröter, M. et al., Interregional flows of ecosystem services: Concepts, typology and four cases. *Ecosystem Services*, **31**, pp. 231–241, 2018. DOI: 10.1016/J.ECOSER.2018.02.003.
[23] Speak, A. et al., The influence of tree traits on urban ground surface shade cooling. *Landscape and Urban Planning*, **197**, 103748, 2020. DOI: 10.1016/j.landurbplan.2020.103748.
[24] Alavipanah, S. et al., The role of vegetation in mitigating urban land surface temperatures: A case study of Munich, Germany during the warm season. *Sustainability*, **7**(4), pp. 4689–4706, 2015. DOI: 10.3390/su7044689.
[25] Rahman, M.A. et al., Comparing the transpirational and shading effects of two contrasting urban tree species. *Urban Ecosystems*, **22**(4), pp. 683–697, 2019. DOI: 10.1007/s11252-019-00853-x.
[26] Rink, D. & Schmidt, C., Afforestation of urban brownfields as a nature-based solution: Experiences from a project in Leipzig (Germany). *Land*, **10**(9), p. 893, 2021. DOI: 10.3390/land10090893.
[27] Lehnert, M. et al., Summer thermal comfort in Czech cities: measured effects of blue and green features in city centres. *International Journal of Biometeorology*, **65**(8), pp. 1277–1289, 2021. DOI: 10.1007/s00484-020-02010-y.
[28] Lindén, J., Fonti, P. & Esper, J., Temporal variations in microclimate cooling induced by urban trees in Mainz, Germany. *Urban Forestry and Urban Greening,* **20**, pp. 198–209, 2016. DOI: 10.1016/j.ufug.2016.09.001.
[29] Georgi, J.N. & Dimitriou, D., The contribution of urban green spaces to the improvement of environment in cities: Case study of Chania, Greece. *Building and Environment*, **45**(6), pp. 1401–1414, 2010. DOI: 10.1016/j.buildenv.2009.12.003.
[30] Kraemer, R. & Kabisch, N., Parks under stress: Air temperature regulation of urban green spaces under conditions of drought and summer heat. *Frontiers in Environmental Science*, 10, 2022. DOI: 10.3389/fenvs.2022.849965.
[31] Sgrigna, G. et al., Relationships between air particulate matter capture efficiency and leaf traits in twelve tree species from an Italian urban–industrial environment. *Science of the Total Environment*, **718**, 137310, 2020. DOI: 10.1016/j.scitotenv.2020.137310.
[32] Buccolieri, R. et al., The impact of trees on street ventilation, NOx and $PM_{2.5}$ concentrations across heights in Marylebone Rd street canyon, central London. *Sustainable Cities and Society*, **41**, pp. 227–241, 2018. DOI: 10.1016/j.scs.2018.05.030.

[33] Marando, F. et al., Removal of PM_{10} by forests as a nature-based solution for air quality improvement in the metropolitan city of Rome. *Forests*, **7**(12), p. 150, 2016. DOI: 10.3390/f7070150.
[34] García-Gómez, H. et al., Atmospheric pollutants in peri-urban forests of Quercus ilex: evidence of pollution abatement and threats for vegetation. *Environmental Science and Pollution Research International*, **23**(7), pp. 6400–6413, 2016. DOI: 10.1007/s11356-015-5862-z.
[35] Frantzeskaki, N., Seven lessons for planning nature-based solutions in cities. *Environmental Science and Policy*, **93**, pp. 101–111, 2019. DOI: 10.1016/j.envsci.2018.12.033.
[36] Horváthová, E., Badura, T. & Duchková, H., The value of the shading function of urban trees: A replacement cost approach. *Urban Forestry and Urban Greening*, 62, 127166, 2021. DOI: 10.1016/j.ufug.2021.127166.
[37] Uhlhorn, B., Nachhaltigkeitsbewertung von Straßenbegleitgrün am Beispiel der Stadt Wels. Masters thesis, University of Natural Resources and Life Sciences, 2021.
[38] Badura, T. et al., Public support for urban climate adaptation policy through nature-based solutions in Prague. *Landscape and Urban Planning*, **215**, 104215, 2021. DOI: 10.1016/j.landurbplan.2021.104215.
[39] Wang, X. et al., Tree species richness and diversity predicts the magnitude of urban heat island mitigation effects of greenspaces. *Science of the Total Environment*, **770**, 145211, 2021. DOI: 10.1016/j.scitotenv.2021.145211.
[40] Simões Aelbrecht, P., Stevens, Q. & Kumar, S., European public space projects with social cohesion in mind: Symbolic, programmatic and minimalist approaches. *European Planning Studies*, **30**(6), pp. 1093–1123, 2022. DOI: 10.1080/09654313.2021.1959902.
[41] Bridge, G., Butler, T. & Lees, L., Gary Bridge, Tim Butler and Loretta Lees (eds.) (2012), Mixed Communities: Gentrification by Stealth? Bristol: Policy Press. £70, pp. 372, hbk. *Journal of Social Policy*, **42**(1), pp. 170–172, 2013. DOI: 10.1017/S0047279412000621.
[42] Berking, H., *Negotiating Urban Conflicts: Interaction, Space and Control*, Transcript: Bielefeld, 2006.
[43] Zuniga-Teran, A.A. et al., The unjust distribution of urban green infrastructure is just the tip of the iceberg: A systematic review of place-based studies. *Environmental Science and Policy,* **126**, pp. 234–245, 2021. DOI: 10.1016/j.envsci.2021.10.001.
[44] Crossley, A.J. & Russo, A., Has the pandemic altered public perception of how local green spaces affect quality of life in the United Kingdom? *Sustainability*, **14**(13), p. 7946, 2022. DOI: 10.3390/su14137946.
[45] Henninger, S. & Weber, S., *Stadtklima*, Ferdinand Schöningh: Paderborn, 2020.

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EFFECTIVE URBAN CLIMATE ADAPTATION IN THE GLOBAL SOUTH? GOVERNANCE LESSONS FROM LILONGWE CITY, MALAWI

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ABSTRACT

Cities across the world are increasingly at risk of environmental challenges, including extreme weather events. The experiences and therefore the responses to such challenges are highly varied. Through the lens of the southern urban critique, such differences are also evident between cities in the global south and global north since "southern cities are socially, materially, culturally, politically and/or historically different from northern cities". Although this is the case, scholars and practitioners have often ignored such apparent differences when theorising, planning and implementing responses to climate impacts. Oftentimes, such obfuscating of the differences risks maladaptation. This is particularly critical since climate impacts are fundamentally shaped through the processes that create the city. Hence, the differences in the processes across cities vitally entails differences in the impacts experienced and observed, and therefore differences in the responses. This paper aims to demonstrate how adaptation to climate change is governed and implemented in Malawi's cities. Using a postcolonial approach, it firstly discusses the historical and contemporary production of risk to floods in "informal" settlements. Further, it draws attention to how citizen participation is operationalised in policy planning and implementation processes in addressing urban flood risks. Taking a qualitative approach, the research employed document analysis, focus group discussions and interviews with community leaders, officials from both government agencies and departments and non-governmental organisations working on flood risk management in "informal" settlements in Lilongwe city. The findings foreground how responses to climate change and extreme weather events are at once informed and thwarted by historical and contemporary governance processes across spatial scale. This paper, therefore, affirms the need to adopt the southern urban critique approach in theorising, planning and implementing responses to climate change

Keywords: flood risk, governance, informal settlements, southern urban critique.

1 INTRODUCTION

The vulnerability of cities, globally, to environmental challenges is well-known. However, most urban studies have focused on the "global north" cities to theorise and understand how the urban is affected and responds to current and future challenges. This is problematic in myriad ways. Chiefly, cities in the global south "are socially, materially, culturally, politically and/or historically different from northern cities" [1, pp. 7–8]. This, therefore, calls for different and context-specific theoretical and epistemological approaches to be employed to understand different cities.

Flood risks are a social and political construct [3], [4], especially as climate impacts are fundamentally shaped through processes that create the city [2]. In this sense, in southern cities, colonial encounters and succeeding governance processes create the current vulnerabilities to floods experienced by particular social groups in particular locations in cities. This understanding has, thus, led to the call for researchers in climate and disaster risk studies to go beyond focusing on "root causes of vulnerability" by including "root causes of the hazardscape" when researching and managing flood risk in southern cities [5, p. 184]. This invitation is the starting point and the core of this paper.

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This study therefore seeks to foreground how flood risk in Lilongwe city is a product of colonial and postcolonial encounters and the ways in which current governance processes are (in)effective in significantly reducing the risk. Ultimately, the paper attempts to advance the proposition that governance processes seeking to address flood risk must adequately be guided by the experiences of the vulnerable with serious and particular attention on historical political and social processes. In this way, the study responds to the invitation of considering "contexts and practices shaping southern cities" [1, p. 14] and goes beyond this invitation by focusing on the production and governance of urban flood risk. The remainder of this paper, therefore, proceeds by discussing the historical and contemporary political production of flood risk through land marketisation and other land management policies. Then, I discuss how citizens are engaged in governance of flood risks in Lilongwe city and how these affect the implementation of strategies for managing urban flood risk in the city. Before going into this discussion, however, I describe the methodology adopted in this study.

2 METHODOLOGY

This paper draws from empirical work conducted as part of my PhD research. The research focused on Lilongwe city in Malawi (see Fig. 1). The city was chosen because it has been experiencing an increase in the frequency and intensity of floods over recent years. Lilongwe is the capital city of Malawi, since 1975. It has a population of at least 989,318 [6], with over 76% of this population residing in informal settlements [7].

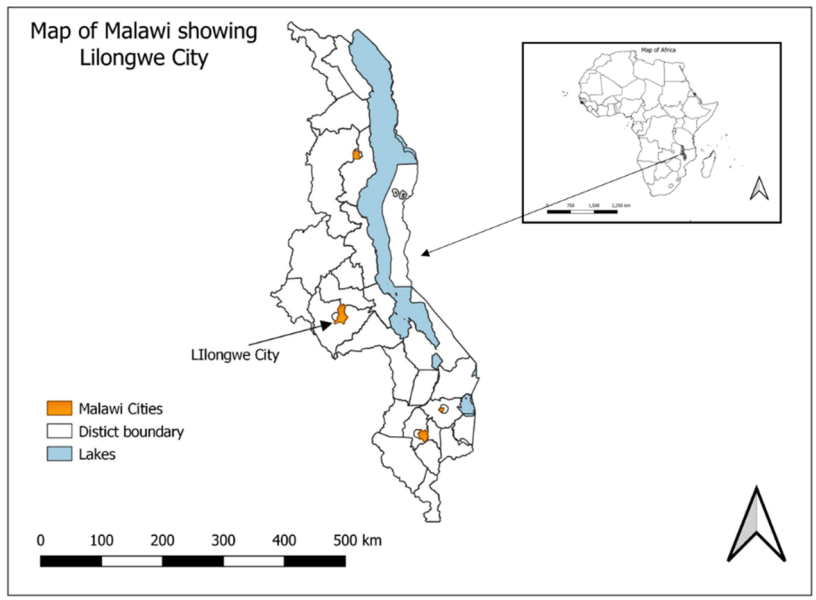

Figure 1: Map of Malawi showing Lilongwe city.

Taking a qualitative approach, this study employed document analysis, in-depth interviews and focus group discussions to understand the historical production of risk and citizen participation in the governance of flood risk. Semi-structured interviews targeted officials working with state and non-state institutions at city and national level in addition to community leaders and representatives of Ward civil protection committees in Kawale

settlement. Four focus group discussions were also held with community members in Kawale to understand the shared experiences of flood risk governance processes implemented in their area.

As part of a PhD research involving human subjects, ethical considerations were paramount. Ethical approval was granted by the University of Glasgow. Two key ethical issues were considered: obtaining an informed-consent and ensuring anonymity and confidentiality. All participants involved in this research, therefore were well-informed about the project and how the data is going to used and their right to pull out of the study at any point. Further, their anonymity was guaranteed. Thus, in order to protect the identity of research participants, pseudonyms are used to refer to all participants in this paper.

3 HISTORICAL AND CONTEMPORARY PRODUCTION OF FLOOD RISK: OF SEGREGATIVE LAND MANAGEMENT POLICIES AND PROCESSES

The production of flood risk in Malawi can be traced from governance processes during the colonial period. This is mainly through the unequal access to land and the eventual settlement of the poor in parts of the cities more vulnerable to floods. It is important to mention that urban development in Malawi was slightly different from other African countries due to low interest from the colonialist owing to the lack of minerals [8]. For clarity and brevity, in this paper, I focus on two main processes that I argue led to the production of flood risk in urban Malawi: the marketisation of land and the state's adoption and advancement of segregative policies.

3.1 Marketisation of land

Prior to the arrival of the white settlers and the colonialists, land was managed through traditional systems. In traditional African systems, selling land is alien because they believe land belongs to not only the present but also the future generation [9]. Thus, though land was seen to be managed by the Chiefs, they were mere custodians of the land. Their role was limited to allocation of land and settling land disputes; neither did they have the powers to sell nor evict people from their land [10]. Thus, the white settlers who came in the 1800s introduced the sale of land concept which was alien but also incomprehensible for the native. This system of accessing land, therefore, favoured the white settlers unlike the Black natives.

In order to drive his agricultural commercialisation agenda, Harry Johnstone, the first Commissioner and Consular General of Nyasaland (Malawi's name during the colonial rule), decided to legally allocate land to white settlers through issuance of a "certificate of claim" as evidence of land ownership. This issuance of certificate of claim marked the "the inception of the private land system" [11, p. 31] in Nyasaland. The process of issuing these certificates, however, was marred with fraud as some claims were based on shady deals and limited documentation evidence [12, p. 77], effectively alienating native from their land.

Besides the private land ownership, the colonial administration also introduced the public land ownership under which all land managed by chief before the colonisation was ceded to the Crown. The Crownland made up 85% of all land in Malawi. With most of the land designated as either private or crown land, there was minimal land left for the majority-Black natives. Owing to this, colonisation inevitably introduced tenancy. By 1958, for instance, annual rent fees for natives on private estates were about 52 shillings and 6 pence, triple the statutory monthly wage of unskilled labour [11]. Through orders and contested claims, Africans were reduced to tenants in their own land. Although the two land systems were technically different, they served the same purpose: to benefit the capitalist agenda of the non-natives.

This marketisation of land continued post-independence. As soon as the Malawi gained independence led by President Hastings Banda, the state adopted new legal instruments in land management. On one hand was the Customary Land Act (Cap 59.01) of 1967 whose goal was to improve agricultural productivity in order to "accelerate the transition from a subsistence to a cash economy" [13, p. 695]. Thus, the purpose of the Customary Land Act (Cap 59.01) of 1967, was to promote and facilitate the conversion of customary land to private land. On the other hand, the Registered Land Act provides for the "registration of title to land and for dealings in land so registered and for the purposes connected therewith" where registration as conceived in the Act "confers the right of ownership as private land". The synchronous enactment of the two acts, in principle, encouraged private ownership of land, as opposed to customary use. This move, therefore, enabled a development of classes based on "ownership" of land, as few people (elite) could afford to "own" land. Reinforcing these acts is the Land Acquisition Act of 1965 which was designed to facilitate the transfer of land from smallholder farmers to large estate farmers [14]. These estate farmers included cabinet ministers, members of parliament, party functionaries and senior civil servants, most with direct support from President Banda [15, p. 10]. The implementation of the Land Acquisition act therefore accentuated the dispossession of the poor while enabling the rich, in post-colonial Malawi.

3.2 Policies and socio-spatial segregation

Besides the marketisation of land, other policies explain the political and social construction of flood risk enunciating the root causes of the hazardscape viz why poor people are located in vulnerable locations in Malawi's cities such as Lilongwe. After the first World War, there was noticeable growth in urban population due to rural–urban population fuelled by economic growth. The Township ordinance of 1931 provided for the establishment and composition of townships. Although this was done, councillors did not represent the "indigenous people" or Africans (Chiweza 2007, as cited in [16]). The welfare of Africans, in contrast, was under the jurisdiction of traditional governance systems. This arrangement meant that "the little urban planning that existed was not intended for indigenous needs" [16, p. 446].

Further, in urban settlements, the spatial organisation during the colonial rule revealed clear fragmentation. John McCracken succinctly summarises the extent and significance of this colonial fragmentation:

> In their different ways, the settlements like Blantyre, Limbe, Zomba and Lilongwe epitomised the colonial imagination at its most vivid in the way that urban space was ordered into precisely designated functions, normally involving the segregation of the European zone from Asian and African sections [12, p. 282].

In Lilongwe, in 1924, the natives were ordered to move and to live on the eastern bank of the Lilongwe River located in the Southern part of the town, while the wealthy lived on the western bank, North and Central part of the town [17]. The western bank was the higher ground considered free from malaria vectors and diseases, therefore safe for the Europeans. The Southern part of the city consisted of unplanned settlements which were excluded from crucial infrastructures such as water supply, in favour of the Northern and Central part of the town [18]. On the eastern bank of Lilongwe River, the Asian-occupied area acted as a buffer between the African and European settlements. Further, on the same Eastern bank of Lilongwe River, African civil servants in the colonial government were housed in temporary

structures made of mud and thatched with grass [17]. More small permanent houses for native civil servants were only developed in the 1950s, on the eastern bank of Lilongwe River in the Falls Estate area [17]. After independence, the European zones were taken over by civil servants and high-income people while low-income groups remained in the African zones of the urban areas.

Such socio-spatial segregation was continued post-independence. The adoption and continuation of zoning in urban planning seemed to follow the class-racial lines apparent during the colonial times. The Lilongwe outline zoning scheme of 1986 (Fig. 2), informed by the Lilongwe Master Plan of 1969 clearly illustrates this.

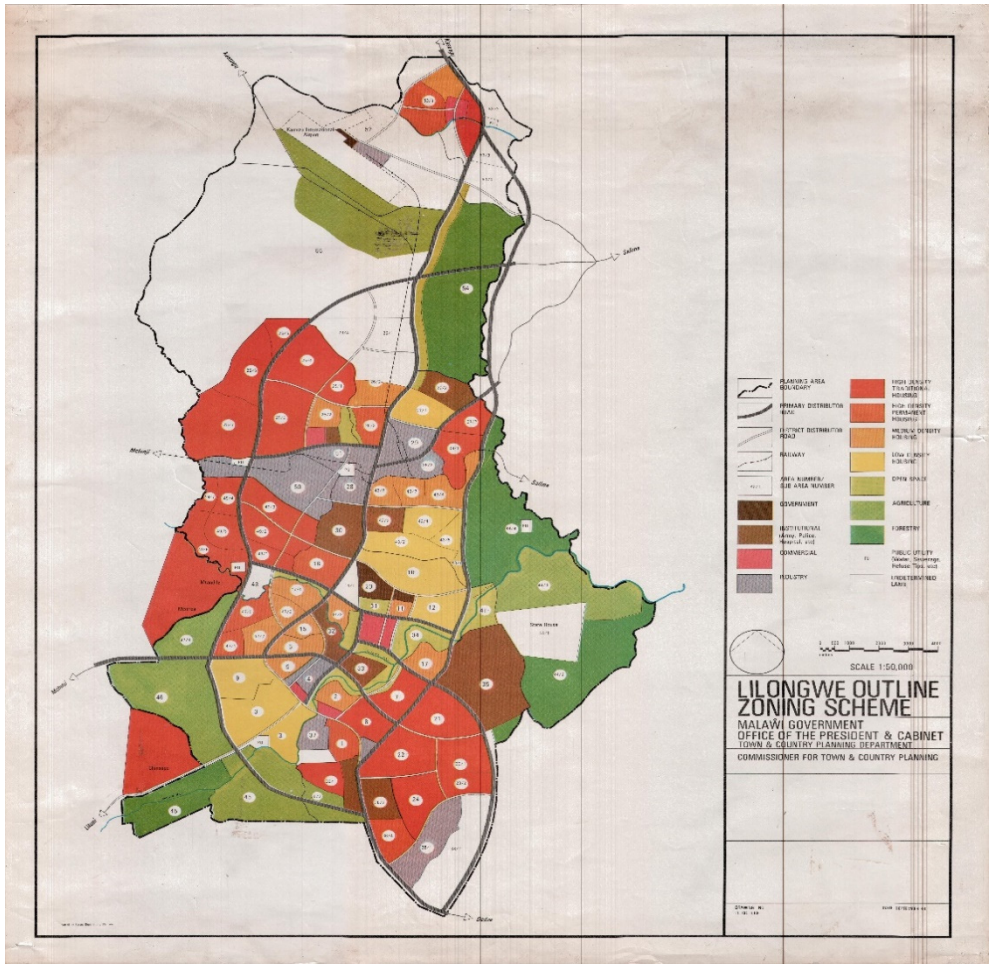

Figure 2: Lilongwe city Outline Zoning Scheme of 1986. *(Source: Town and Country Planning Department.)*

Clearly, the above Outline Zoning Scheme and the Lilongwe Master Plan on which it was based, reproduced the segregation of residential zones as evidenced by the location of low income settlements in the periphery of the city [8]. In this regard, the policy instruments

visibly demarcated Lilongwe into three main sections: European, Asian and African sections, with low-income settlements located away from the city centre making Lilongwe "a true replica of the spatial configuration of an apartheid city" [17, p. 100]. Worth noting, too is the demonstration of prejudices of the government as seen in the Outline Zoning Scheme, for instance, through the siting of the police headquarters between the Capital hill (area housing all government ministries and department headquarters – marked 20 on the Outline Zoning Scheme) and the largest traditional housing area (Marked 25 on the Outline Zoning Scheme) which was arguably due to "a somewhat suspicious attitude towards the low-income urban population" [8, p. 285]. Such racial and class exclusionary underpinnings in the land planning instruments are a vivid continuation of colonial era land management processes and extremely similar to, and are a continuation of, land planning approaches from the colonial era.

The case of Lilongwe illustrates the extent of socio-spatial segregation that has defined urban life and how different people experience the urban differently. This was similarly experienced in Nairobi which had Asian, European and African zones "distinguishing their economic status, lifestyle and the political power each zone welds" [19, p. 20]. The effects of ignoring the African migrant/resident in urban areas have prevailed and unfortunately, informed current urban governance strategies to the present day. The present day has seen the inequalities from the colonial era lead to "a disproportionate amount of land, infrastructure and services benefit a few while the majority are congested with few or no services" [20, p. 50].

Additionally, there were differences in the availability of infrastructure across the country. The bulk of infrastructure, particularly road and transportation networks, was developed in the southern region [21] where most European owned estates were located. This infrastructure was to service the White minority settlers and the cash crop industry. This is unlike in the central region and northern region which had minimal white settler population. Both the socio-spatial segregation and infrastructural inequalities have therefore led to differentiated vulnerability to floods the Lilongwe city.

As experienced in the past flood events, the most affected in Lilongwe city, the floods of 2015 mostly affected residents of Kawale and Mtandire, informal settlements. High and middle-income areas neighbouring these settlements i.e. Area 2 for Kawale and Area 47 for Mtandire did not experience the same effects of the floods. The main reason for this disparity, as research participants reported, is that the informal settlements do not have access to drainage and waste management services provided by the city council. Thus, the poor drainage and waste management systems increases the vulnerability of the residents as in case of heavy rainfall event, management of flood waters a challenge. Following these flood events, national and city authorities have been engaging the public in urban flood risk management.

4 TRACING CITIZEN PARTICIPATION IN URBAN FLOOD RISK GOVERNANCE

4.1 Participation in governance processes

The governance of flood risk management in Malawi is led by the Department of Disaster Management Affairs. However, governance at city level is spearhead by the local government structure through which citizen participation, ideally, is mobilised. However, citizen participation in governance of flood risk in Lilongwe is limited. The limitation is mainly due to the governance structure and engagement processes adopted.

To begin with, following the decentralisation policy, citizens' involvement in governance processes is often through their elected representatives to the local council. The councillor is assumed to represent the will and aspirations of the people they are representing. According to the Local Government Act of 1998 and its amendment act of 2010, the council includes the following members from within the local government area: (1) elected member from the ward (Ward Councillor), (2) Members of Parliament, (3) Traditional authorities; and (4) five people appointed by the elected members to cater for the interests of special groups as the Council may deem necessary (see Fig. 3).

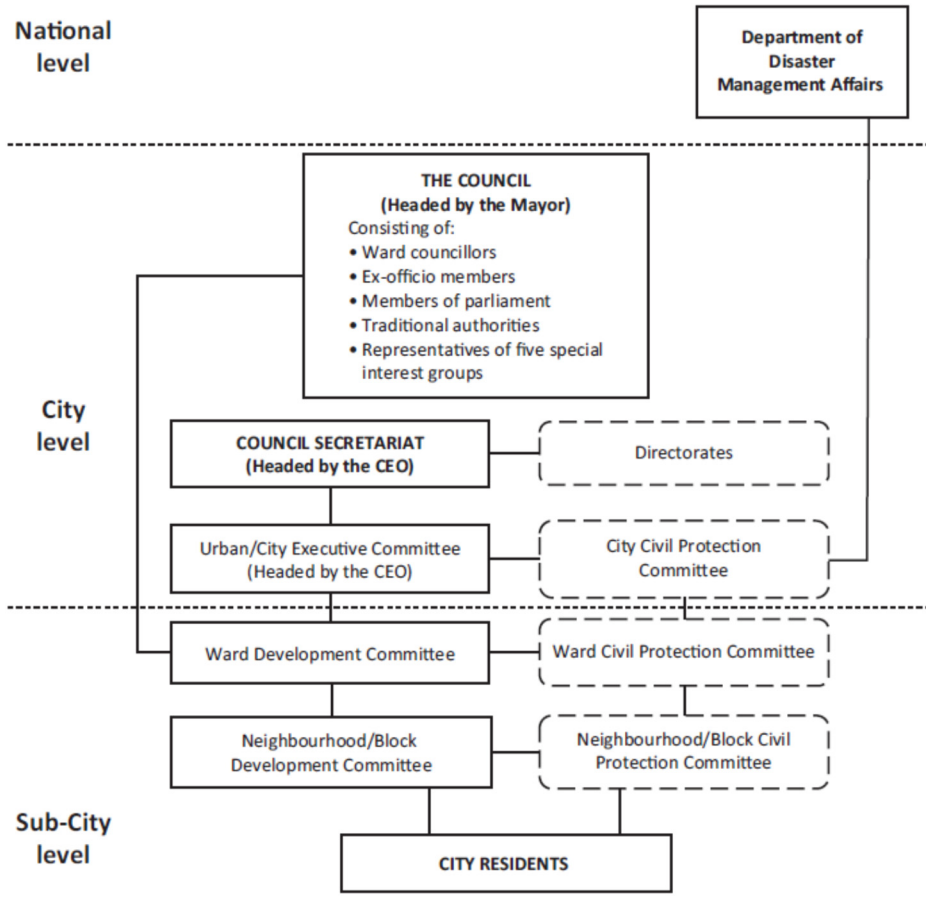

Figure 3: Local government structure [24].

However, besides the council, the local government structure has the council secretariat which is the main "liaison" between the council and the central government and of particular mention here is the DoDMA. The secretariat provides technical and administrative support to the council. This element of the local government system is therefore considered "subordinate to local councillors" as it is there to implement the decisions and policies made by the councillors [22]. Worth noting is that the secretariat is headed by a Chief Executive Officer who also heads the Urban/City Executive Committee constituting heads of

departments/sector offices, and in some instances representatives from NGOs. It is this part of the council that leads in the governance of the resilience to floods in the city through the City Civil Protection Committee (CCPC), a subcommittee of the Urban/City Executive Committee. The CCPC is the main body coordinating the implementation of disaster risk management plans and policies in the city in conformity to the prevailing national policies and frameworks. The CCPC, among its numerous responsibilities, advises the City Executive Committee on disaster risk management issues and submits reports to DoDMA [23]. At ward level, the CCPC works with the Ward Civil Protection Committees (a subcommittee of the Ward Development Committee) and further below at Block/Neighbourhood level, the CCPC works with Block Civil Protection Committees (subcommittee of the Block/Neighbourhood Development Committee).

The way the governance local governance structure is laid out, particularly at city and sub-city levels, brings to the fore a critical loophole for effective participation and this is problematic as most stakeholder engagements in urban Malawi target local government structures [24]. By virtue of the CCPC being under the secretariat, it reduces the power of the elected council members in managing the resilience-enhancing activities implemented in the city. These elected council members, are supposed representatives of the people, hence demanding their participation in the governance of urban resilience. The eventual handling of all disaster risk management issues by the CCPC, therefore, effectively marginalises the voice of the people and recentralizes power to the state in the implementation of resilience-enhancing activities at the city level.

4.2 Participation in policy prioritisation and its successes/failures

Direct citizen participation in governance processes is also limited. With respect to direct citizen participation, Arnstein's [25] typology is useful to understand the extent of participation and extrapolate the benefits thereof. For Arnstein, participation has different levels which can be represented by eight (8) rungs of a ladder, with the lowest level/rung being Manipulation and the highest level/rung being direct Citizen control. The level of participation increases with "the extent of citizens" power in determining the end product [25, p. 217]. Using Arnstein's [25] typological lens, therefore, participation of citizens in the governance of resilience-enhancing mechanisms is largely at rung 4; Consultation or below. This is manifested in myriad ways. Indicative is one of the responses of a Focus Group Discussion participant on how they, as citizens, are involved in the planning and implementation of resilience-enhancing activities:

> The problem that the government has, not only the current government but even the previous government, is that they do not use decentralisation approach. They do not use democratic principles…What is needed is that before the construction work begins, they should invite community members to get their input on how best the construction could be done. The communities should give their input and so too the engineers. Then they should balance what the community members are saying and what they read in books to decide on what they should do… But they don't listen! (Yohane, 19-11-2019).

These sentiments are echoed by an official working with an NGO while commenting on the development of the National resilience strategy:

> Full of nonsense. It's full of nonsense. I can't even read that one, it's a waste of time because it has been developed by people sitting in the offices. It hasn't

> been developed by the communities. It has been developed by people who sit in the offices… Those people cannot develop policies that would reflect the needs of people in Mtandire (Chisomo, 25-10-2019).

While the respondent acknowledged that the Lilongwe city council had involved communities in the development of the city resilience strategy, they attributed the move to the fact that the programme was funded by the UN-HABITAT. As such, the respondent implies the approach to involve communities was purely due to the donor's influence. This is unsurprising as donors have been found to influence participation in governance processes in developing countries [26], [27], mostly through conditionalities attached to aid.

Nevertheless, for the limited participation activities that are conducted, citizens are often invited by state or non-state organisations to such participatory spaces. The successes of such invited spaces is limited. A good example of this is a case where city council officials were reported to urge and promote relocation as the most effect way of dealing with the flood incidences and its effects. Some of the representatives of the community reported how they agreed to the proposition when invited to a meeting organised by the city council with the hope to be able to convince their communities when they return. This proposition was vehemently rejected by the communities and such opposition was also registered in one focus group discussion:

> There is a threat that the government just wants to relocate all those that stay near riverbanks and that's what is making us wonder that where are they taking us to? We don't like the idea. Their role is that the issues that we've told you here, about tree planting, they should just help us with that but about relocation, where are we going to go? (Phiri, 19-11-2019).

The use and limitations of invited spaces of participation has been extensively discussed in literature [28]–[30]. This case, however, highlights two fundamental theoretical points. First, the limitations of invited spaces. The invited spaces are choreographed and framed by the initiating party while the invited party conforms and goes along with the pre-determined setup. This limits the effectiveness of such engagements and the benefits thereof. More spaces created by the community members themselves would strengthen their voices and possibly be sources of effective strategies to reduce flood risk in informal settlements. Second, the case reflects the different ways in which contestation is done in this informal settlement. Rather than confrontational approaches prevalent in northern cities, residents here adopt a rational way to contest the top-down policies adopted by authorities to manage urban flood risk; non-engagement. They do not cooperate besides agreeing, albeit through their representatives, to undertake particular flood risk management strategies. The case of Kawale residents therefore demonstrates a form of political contestation which highlights the "unseen forms of agency and resistance" [31, p. 223] advanced by the southern urban critique.

5 CONCLUSION

The findings foreground how flood risk is a product of colonial and postcolonial social and political processes. In Lilongwe city, the causes of the prevalent flood hazardscape are well-understood when colonial encounters and postcolonial processes are read together to inform strategies for managing urban flood risk. The current governance strategies for ensuring citizen participation in flood risk management, however, are limited by structural and processual factors. While the governance structures by their design recentralise power to the state, the particular engagement strategies do not adequately give the power to citizens to significantly influence policies. Ultimately, the successes of responses to climate change and

extreme weather events like floods are compromised. While this research centred on political and social processes producing flood risk in Lilongwe city, further research on how other contextual processes such as religion, ethnicity and culture would bring in critical nuances in understanding the production of urban flood risk at a microscale.

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REFERENCES

[1] Lawhon, M. & Truelove, Y., Disambiguating the southern urban critique: Propositions, pathways and possibilities for a more global urban studies. *Urban Studies*, **57**, pp. 3–20, 2020. DOI: 10.1177/0042098019829412.
[2] Bulkeley, H., *Cities and Climate Change*, Routledge: Oxon, 2010. DOI: 10.1787/9789264091375-en.
[3] Hidalgo-Bastidas, J.P. & Boelens, R., The political construction and fixing of water overabundance: Rural–urban flood-risk politics in coastal Ecuador. *Water International*, **44**, pp. 169–187, 2019. DOI: 10.1080/02508060.2019.1573560.
[4] Salami, R.O., von Meding, J.K. & Giggins, H., Urban settlements' vulnerability to flood risks in african cities: A conceptual framework. *Jamba: Journal of Disaster Risk Studies*, **9**, pp. 1–9, 2017. DOI: 10.4102/jamba.v9i1.370.
[5] Benjamin, M.A., Analysing urban flood risk in low-cost settlements of George, Western Cape, South Africa: Investigating physical and social dimensions. University of Cape Town, 2008.
[6] Government of Malawi, 2018 Malawi Population and Housing Census Main report. Zomba, 2019. DOI: 10.1097/01.gim.0000223467.60151.02.
[7] United Nations Human Settlements Programme, Malawi: Lilongwe Urban Profile. UN Habitat Human Settlements Programme, 2011.
[8] Potts, D., Urbanisation in Malawi: With special reference to the new capital city of Lilongwe. University College, London, 1986. DOI: 10.1515/9783112523384.
[9] Mwathunga, E. & Donaldson, R., Urban planning history of Malawi: Case study of the capital Lilongwe. *Planning Perspectives*, pp. 1–21, 2021. DOI: 10.1080/02665433.2021.1988867.
[10] Mkandawire, R.M., The land question and agrarian change. *Malawi Crossroads Post-Colonial Polit. Econ*., ed. G. Mhone, SAPES Books: Harare, 1992.
[11] Ng'ong'ola, C., The state, settlers, and indigenes in the evolution of land law and policy in colonial Malawi. *The International Journal of African Historical Studies*, **23**, pp. 27–58, 1990.
[12] McCracken, J., *A History of Malawi, 1859–1966*, Boydell and Brewer, 2012.
[13] Pachai, B., Land policies in malawi: An examination of the colonial legacy. *The Journal of African History*, **14**, pp. 681–698, 1973. DOI: 10.1017/S0021853700013116.
[14] Stambuli, P.K., *Political Change, Economic Transition and Catalysis of IMF/World Bank Economic Models: The Case of Malawi*, 2002.
[15] Cammack, D., Kelsall, T. & Booth, D., Developmental the case of Malawi, Working Paper, London, 2010.

[16] Riley, L., Operation Dongosolo and the geographies of urban poverty in Malawi. *Journal of Southern African Studies*, **40**, pp. 443–458, 2014. DOI: 10.1080/03057070.2014.913425.
[17] Kalipeni, E., The spatial context of Lilongwe's growth and development in Malawi. *Sacred Spaces Public Quarr. African Econ. Cult. Landscapes,* eds E. Kalipeni & P.T. Zeleza, African World Press: Lawrenceville, pp. 72–108, 1999.
[18] Tiwale, S., Rusca, M. & Zwarteveen, M., The power of pipes: Mapping urban water inequities through the material properties of networked water infrastructures: The case of Lilongwe, Malawi. *Water Alternatives*,**11**, pp. 314–335, 2018.
[19] Matende, M.A., Planning for housing the economically weak secio of the urban population: A case study of selected site and service schemes in Nairobi. University of Nairobi, 1977.
[20] United Nations Human Settlements Programme, Malawi urban housing sector profile. Nairobi, 2010.
[21] de Haan, L., de Jong, J. & Sterkenburg, J., A planning survey of the northern region, Malawi, 1975.
[22] Kanyongolo, F., Administrative law and governance in East Africa research project: Local government in Malawi (Draft 1), 2018.
[23] Government of Malawi, Operational Guidelines for Disaster Risk Management, p. 197, 2013.
[24] Zimba, J.M., Simbeye, B. & Chirwa, S.C., Towards intergenerational equity: Analysis of youth engagement strategies in climate action planning in mzuzu, Malawi. *Urban Planning*, **6**, pp. 309–320, 2021. DOI: 10.17645/up.v6i4.4383.
[25] Arnstein, S.R., A ladder of citizen participation. *Journal of the American Planning Association*, **35**, pp. 216–224, 1969. DOI: 10.1080/01944366908977225.
[26] Molenaers, N. & Renard, R., Strengthening civil society from the outside? Donor-driven consultation and participation processes in poverty reduction strategies: The Bolivian Case, p. 32, 2002.
[27] Winters, M.S., Accountability, participation and foreign aid effectiveness. *International Studies Review*, **12**, pp. 218–243, 2010. DOI: 10.1111/j.1468-2486.2010.00929.x.
[28] Cuppen, E., The value of social conflicts: Critiquing invited participation in energy projects. *Energy Research and Social Science*, **38**, pp. 28–32, 2018. DOI: 10.1016/j.erss.2018.01.016.
[29] Aiyar, Y., Invited spaces, invited participation: Effects of greater participation on accountability in service delivery. *India Review*, **9**, pp. 204–229, 2010. DOI: 10.1080/14736489.2010.483370.
[30] Morange, M., Participation, neoliberal control and the voice of street traders in Cape Town: A Foucauldian perspective on 'invited spaces'. *Pop. Polit. South African Cities. Unpacking Community Particip*., HSRC Press, pp. 171–195, 2015.
[31] Truelove, Y. & Cornea, N., Rethinking urban environmental and infrastructural governance in the everyday: Perspectives from and of the global South. *Environment and Planning C: Politics and Space*, **39**, pp. 231–246, 2021. DOI: 10.1177/2399654420972117.

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PLANNING FOR NATURAL HAZARDS: AN INTEGRATED APPROACH INTO URBAN RISK ASSESSMENTS – A PERSPECTIVE ON SETTLEMENTS LOCATED IN HIGH-RISK AREAS IN MASERU, LESOTHO

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ABSTRACT

With the advent of climate change and increasing urbanisation of the cities and towns, poor new residents in urban and peri-urban areas settle in high-risk locations with limited access to basic services and unfit structures which cannot resist harsh weather conditions. Therefore, managing and proactively identifying the risk by applying proper urban management and governance tools will improve the safety and liveability of cities. Maseru, like many other African cities, does not have proactive planning for natural disasters, and there is a common development of new settlements and extension of older settlements into high-risk locations. The majority of these settlements are located in areas susceptible to rockfalls and flash floods. Consequently, this paper focuses on planning for natural hazards in high-risk located settlements. A hazard impact assessment is conducted to measure the hazard risk and identification of physical assets and populations at high-risk hazards areas. A mixed method approach is used which includes an analysis of documents. Also, an observation and a transect walk and secondary data is utilised for the primary level risk assessment. The results of this study revealed that there is no planning for natural hazards in Lesotho. The results further reveal that more people are building in high-risk locations because these places are not zoned to alert people that they cannot reside within them. The study, therefore, recommends a clear working relationship between the Maseru Municipal Council and the Disaster Management Authority, to sensitise people about the dangers of constructing houses in high-risk locations. High-risk locations should be assessed properly by engineers and rezoned to prevent people from residing on them.

Keywords: high-risk location, natural hazards, climate change, rockfall, flash floods, urban risk assessment.

1 INTRODUCTION

Many cities of the global south are faced with the challenge of planning and managing natural hazards key amongst most being the floods. Therefore, due to its terrain, Lesotho is generally susceptible to natural hazards and the situation is worsened by the adverse effects of climate change [1]. Hence, heavy summers rainfall between December and March causes flooding in high risk locations in Maseru. Looking at Lesotho's status as a vulnerable and poor country which is generally prone to natural hazards, it is important for her to prepare and plan for these hazards. However, the previous vulnerability assessment indices have only focused on the impact on livelihoods, that is; how disasters have affected the food production and erosison hazard map [2]. In this context, Maseru recently experienced heavy rainfalls that resulted into flooding of settlements located on high risk areas, such as below the dams and witthin the natural water paths. These are areas where if an urban risk assessement index are adequately conducted, there would be no settlements located.

2 NATURAL HAZARDS

Natural hazards are physical phenomenon that occur unexpectedly globally and has major contributions on the landscape of the earth. The natural hazards have always been in existance

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even before the appearance of man, these phenomenon endangers human life because they damage manmade infrastructures and natural features. Furthermore, urban development excerbated the impact of natural hazards more especially in the developing countries, hence it is worth noting that natural hazards tend to occur frequently more than our capabilities to redress the damage they cause [3]. Lesotho is highly exposed to natural hazards as it experiences extreme weather conditions which causes hail storms, floods and heavy snow in winter [4]. In the country, these phenomenon does not occur specifically on specific locations but it is rather influenced by the land size and environment vulnerability. However, it is important to note that natural hazards vulnerability is also increased by the improper land use and unplanned development beside natural occurances only [5].

3 LAND USE PLANNING FOR NATURAL HAZARDS

Land use planning is a key instrument for reducing natural hazards risk and in turn increasing resilience and sustainability. Also, risk-based planning presents an opportunity to plan beyond just natural hazard but to also plan for the aftermath of an event. Equally important, this includes land use assessment and strict planning standards as the risk of hazard increases [6]. In addition, another important issue in risk-based land use planning is the capability to differentiate between various stages of risk such as acceptable and unacceptable and being able to link them to land use policies. Usually, when addressing natural hazards land use planning is based on the probability of the occurance of an event, without considering the consequences linked to the natural hazard events [7]. That is;in most cases urbanization on flood plains seem to increase the probability of flooding hence it causes disasters. Despite building storm water controls and channelization of water through dams, floods thrive in floodplains and damage properties [8]. Most importantly, land use and natural hazards have a two-way relationship because natural hazards have an ability to change the landscape which then affects the land use. But also, changes in land use can as well cause natural hazards [9], [10].

Ultimately, to reduce the risk of natural hazards it is important for planners, decision-makers and engineers to consider the physical constraints of an area and its susceptibility to natural disasters. Therefore, it is worth employing land use planning based on natural hazard maps to be able to conduct land suitability in areas which promote sustainable urban development. This is important as it focuses on land use planning for the reduction of natural hazards of different types such as landslides, land degradation and floods

4 INTEGRATED URBAN RISK ASSESSMENT FRAMEWORK

This is an approach that enables improved understanding of the city's risks froms climate change and disasters. This approach allows for customization in terms of its application depending on availability of data relating to population and hazards, institutional capacity as well as the financial resources. This is done through phases where each level of assessment is linked to gradually detailed and complex tasks [11]. It is important to note that the URA allows for city managers to choose various components from each pillar which have the capability to either individually or collectively improve the risk understanding in a particular city. The structure of URA is such that it can integrate both rapid on-set events such as landslides and floods as well as the slow-on set hazards such as sea-level rise and droughts which are generally associated with the long-term effects of climate change [11].

The URA is based on three important pillars which are institutional, socio-economic and hazard impact. Most importantly, the framework is centred around the hazard impact assessment pillar, whose main purpose is to identify the intensity, type, and where there is potential loss as a result of climate change and future hazards. In actual fact a risk purpots a

hazard, hence vulnerability of the people and the ability to respond [11]. This then means, the assessment considers the institutional roles and socio-economic situation within the city. This helps to understand whether there are agencies that exists with responsibility to manage the risks ascending from climate change and disasters. Similarly, there is a need to identify vulnerable populations and understand their adaptive capacity [11].

Table 1 shows the three levels of urban risk assessment from primary level, secondary and tertiary levels as proposed by the World Bank, it reflects the tasks at each level and objectives to local governments [11].

In the three levels of urban risk assessment framework in Table 1, the primary level is actually based on risk identification. At this level the most important thing is to conduct a base mapping for preparing for disasters and conducting a socio economic profile of the city. Short term plan is to identify the safe routes during the time of disaster and what needs to be done in responding to disasters. Regarding long term planning at this level, the end product should be the development of a new city to avoid high risk areas.

On the secondary level, here an assessment is done in depth, at this point hazard exposure maps are being developed and populations at high risk areas are being identified. Regarding shorterm planning for disaster preparedness, it is worthy to note that at this point an improved understanding of coordination requirements for urban areas is properly planned. Regarding long term planning, the most important issue is to develop building control codes and planning of new development to avoid high risk areas and improve climate adaption measures. These measures are also extended into the tertiary level of assessment. However, at this level a key emphasis is on promoting climate adaption measures by engaging in non-structural and structural measures. It is worth noting that this framework is key in reducing the risk of natural hazards more especially within the urban areas where rapid development also plays a role in exercabating the risk.

5 NEW ZEALAND CASE EXPERIENCES WITH LAND USE PLANNING AND NATURAL HAZARDS

Between 2007 and 2008 the northern region of New Zealand experienced severe flooding with several communities cut off by floodwaters. It is important to note that some towns were repeatedly flooded within a period of 4 months. This was an issue of great concern amongst different categories of people and stakeholders including the then Prime Minister Helen Clark who was concerned about allowing development in high-risk areas and the urgency to relocate the communities to safer areas. During the same period, an issue of allowing development on high risk areas became a concern to the public generally more especially in other regions which were not affected by these floods directly. This prompted the North City Council to decide not allowing new development in undesirable areas for urban growth purposes [12].

Notably, the planning options in New Zealand are shaped by the historical land use decisions which have shaped the risk management choices. Many of the towns are located in high risk areas especially flooding because they were established during the bygone era. Therefore, communities were used to protecting themselves through flood levee banks which were later ineffective because of rapid urban development This is mainly because such works only protect the communities from hazards that are within the design parameters [12].

Although, New Zealand have been facing these challenges regarding natural hazards, some amendments and establishment of new laws focused on land use planning for natural hazards became iminent. It is worth noting that the Resource Management Act of 1991 is one particular act which provides for the sustainable management of natural resources, which

Table 1: Urban risk assessment framework [11].

Urban risk assessment	Tasks	Link to climate change	Objectives/benefits to local government
Primary	Basic institutional mapping for disaster preparedness and response and climate change. Development of a physical base map if one doesn't exist or updating an existing map.	Limited: Generally identifying climate risks based on the information available regarding regional models.	*Short term*: Planning and preparing for disaster (identifying shelters and safe routes in times of disasters, disaster response protocols, accessibility to emergency funds). *Long term*: Planning new city development to avoid high risk areas.
Secondary	In depth institutional analysis for disaster response, climate change adaption and risk management. Hazard exposure maps development and scenario-based risk models.	Risk modelling includes downscaling of regional climate change models.	*Short term*: Improved understanding of policy and coordination requirements for city and necessary interventions for target areas. *Long term*: conducting annual disaster risk management budget, and planning new development to avoid high risk areas, policy/attention for target.
Tertiary	Financial capacity assessment for institutional delivery of resilience building programs. Constant streamlining and assessments of web-based application depicting populations and areas at risk.	Costs of climate change adaptation defined and prioritized. Adaptation strategies for key affected sectors.	*Short term*: Planning for disaster preparedness (Early Warning Systems, ability to simulate losses during a disaster event). *Long term*: engaging in non-structural and structural measures to reduce climate change and disaster risk impacts defined.

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includes climate change and natural hazards management [13]. It requires the communities to avoid the risk of hazards, whereas the greatest challenge is that the responsibility lies with the community to make such decisions and choices. Hence, it does not actually say how they should avoid and mitigate such risks, it is therefore difficult for the communities to stop developing in hazard prone areas because they see development as an eminent social imperitive.

However, the establishment of laws such as Building Act of 2004 have made it better to plan for natural hazards as it does not only provide for what should be done in the aftermath of an event, but also how it is to be done and executed. This law has provisions that hazard related information and warnings about high risk areas should be made available to the general community and this information is a requirement upon the building consent. More also, Authorities in New Zealand have made important strides in an attempt to plan for natural hazards as tools like evacuation and warnings plans have been placed in flood prone areas and this is seen as huge success especially for hazards that have a greater chance of return such as floods [14].

Having looked at this experience, it is worth noting that Lesotho as a country still has a long way to go in terms of land use planning for hazards and early warning systems. The key lesson issue identified with the New Zealand experience is the importance of including climate change and natural hazards in planning law.

6 THE SITUATION IN MASERU CITY, LESOTHO: THE CASE STUDY

Lesotho has some varied topography and as result spatial occurances of the natural hazards is different. The whole country is vulnerable to natural hazards due to it being mountaneus, however the most prevalent to the study area is flash floods and rock fall. About 70% of the population in Lesotho leaves in the fragile mountainous terrain [15]. It is therefore, important to note that the lack of land use planning is also a major challenge because people end up building in high risk areas where they are susceptable to rock falls and flash floods. However, what is common in Maseru is that people tend to locate to these high risk areas because of the expensive plots of flat land.

7 NATURAL HAZARDS STATISTICS

Table 2 presents a summary of events counts for natural hazards, the total deaths caused these hazards as well as the total number of people affected [16].

Table 2: Lesotho natural hazard statistics [16].

Natural hazard 1900–2020	Events count	Total deaths	Total population affected
Drought	8	0	4,148,015
Flood	4	28	2,334
Storm (convective storm)	2	48	85,000

Table 2 shows the natural hazards that Lesotho has endured since 1900s to 2020, these include drought, convective storm and floods. From Table 2 above from 1900 to 2020 there has been eight counts of drought, four event counts of floods as well as two event counts of storms. Also, it is shown that there have been no deaths caused by drought, but floods have caused a total of 28 deaths during the same period. Similarly, convective storms have caused 48 deaths, with total population of 85,000 affected. Also the floods have affected 2,334 people in total within the same period, while 4,148,015 people in Lesotho have been affected by the drought between 1900–2020. From this statistics we can deduce that drought is more

common in Lesotho as compared to floods and storm. However, flood causes more damage than drought as more people have died from it and similarly convective storm is more deadly than both floods and drought. While drought may not have a direct relationship to unplanned development, we can deduce that floods may have a direct relation to unplanned development because they are mostly riverine floods. Also, when comparing the total deaths between these hazards, the no deaths by droughts are a reflection of less physical vulnerability caused by this natural hazards but the social vulnerability is very high as it is shown by the total population of 4,148,015 affected. However, the statistists for floods and storms reflect high physical vulnerability due to the total number of 76 deaths. It is worth noting that physical vulnerability is related to topography hence floods and storms are more likely to occur in Lesotho as water flows from the highlands to the lowlands.

8 POLICY DOCUMENT CONTENT ANALYSIS

8.1 Provisions from the Disaster Management Act No. 2 of 1997

This act provides for an establishment of the Disaster Management Authority (DMA);to regulate its functions and to provide for emergencies from natural hazards including mitigation, prevention, preparedness as well as the response measures in the aftermath of a disaster to protect lives and properties. In Section 5(1) the Disaster Management Act provides that the Authority is tasked to prepare a National Disaster Management Plan, which must cover working areas of disaster preparedness, recovery and response and mitigation [17]. Further, in Subsection 2 the provision indicate that the prepared National Disaster Management plan should be integrated into other national development plans. Interestingly, Subsection 3 dictates that this national disaster management plan has to be reviewed on annual bases. However, it can also be reviewed whenever necessary sometimes after a disaster occurred [17]. On the same note, Section 6 articulates the disaster relief plans, it reads that the chief executive of the authority will prepare a national relief plan which then has to be approved by the board and the cabinet. Further in Subsection 2 it is indicated that each district shall have to prepare their own relief plans following the chief executives approval [17].

From this act we can deduce that its provisions are mostly reactionary, it emphasise mostly on what should happen in the aftermath of a disaster. The Act does not give provisions on what is to be done to assist the communities resilient from disasters, though the act provides that a national disaster management plan should be prepared these plans are not prepared.

8.2 Provisions from the Town and Country Planning Act No. 11 of 1980

This act provides for an orderly land development, to improve and preserve the amenities so that economic efficiency will be promoted. Section 5(1) of this acts provides that the commissioner of lands who is the planning authority has to prepare the development plan in respect with areas where it shall apply. Notably, in Subsection 2 it is articulated that the the development plan shall guide development of an areas where it is proposed and how it shall be done through each stage [18]. Interestingly, in Section 9, Subsection 1, the act provides that subject to the prescription of the minister land and building uses may reiceive permission to be developed. When looking at these provisions, one can note that they are development specific and they do not talk to the relationship between different land uses, as opposed to what a land use plan should do.

In as much as in Section 17 the Act outlines the enforcement of the planning control. The situation on the ground does not reflect the enforcement of the land planning control, people build in hazard prone and high risk areas and this process put their lives at risk. However, this act provides that anyone who has been found with non compliance case should be served with an enforcement notice within the period of 4 years from an alleged failure to comply [18]. Furthermore, if found guilty such a person should be liable to a penalty;generally this law is development driven and not land use oriented, hence problematic when it comes to disaster risk management. It provides for land planning control instead of land use control hence it opens a room for the use of discretion when making a decision. The risk of natural hazards is not anticipated in this act hence there is a need for land use regulation that shall incorporate issues of sustainability.

8.3 Provisions from National Strategic Development Plan II 2018/19–2022/23

The NSDP II indicates that Lesotho has over the years experienced harsh weather conditions characterised by heavy rain falls, droughts, floods as well as snowstorms in the highlands areas. Furthermore, the plan articulates that the country is experiencing extreme climate change consequences which forces the limted finances to be directed to relief efforts as opposed to other economic development measures [19]. The plan also emphasises that inadequate physical planning and lack of implementation of existing policies have execarbated environmental degradation. And in return there is inappropriate land use where there is a noticeable sprawl of settlements towards areas that are prone to natural hazards.

Equally important, the NSDP II established the strategic interventions and objectives to address these outlined challenges. Notably, the plan aims to improve the countrys resilience to climate change and to improve compliance and enforcement with environmental standards and regulations [19]. The interventions are that enforcement tools should be developed, and environmental impact assessment and other enforcement tools should be mandatory. Also, the plan outlines that environmental education programmes are to be promoted to raise awareness. As provided by the National Disaster Management Act 1997, the expectation is that the prepared National Disaster Management Plan should be integrated into other national development plans. It is important to note that these plans have not been integrated in the NSDP II. We can deduce from this research study that the country is not well prepared to reduce the risk of natural hazards within the population. When looking into this 5 year strategic plan the risk of these hazards is outlined but the document is silent on how the country is the risk is going to be managed. The implication is that when there is a lack of National Disaster Management Plan, it is difficult to prepare an urban risk assessment to be able map, prepare and to plan a new development to avoid hazard prone areas.

9 RESULTS AND FINDINGS OF THE RISK OF FLOODS BASED ON FIELD OBSERVATION

It is important to note that some natural hazards are excerbated by unplanned development and land use. The distruction of the landscape can contribute to the increase and risk of natural hazards, hence in some cases people decide to build their houses on the flood plains, below dams and lakes. For those that have build their houses on the floodplains and along the natural flow of water it is always a challenge when there is a persistent heavy rainfall. This situation becomes problematic as it causes floods. During an observation of the study area (see Fig. 1), we identified the risk which these households are faced with. They are vulnerable and exposed to rock fall which can cause damage to infrastructure and loss of human life. On the same picture there is a house highlighted in red which is located just below a big rock, should

any thing happen this could lead to a loss of human life and infrastructure. Unplanned use of land is one important component that needs to be down to reduce the risk of natural hazards. This together with lack of urban risk assessment strategy in the planning phase of settlements is a major contribution to the populations vulnerability to natural hazards.

Figure 1: Settlements susceptible to rockfall in Maseru. *(Source: Authors Field Survey, 2022.)*

Figure 2: Flooded houses in Maseru in January 2022 [20].

As shown in Fig. 2, the residents of Borokhoaneng in Maseru experienced flash floods in January 2022. The streets were waterlogged while the houses were flooded. It is worth noting

that during the transect walk it was observed that these floods can mainly be attributed to poor drainage system and channels, also there is car wash around the area which blocks the water collected by the drainages to flow into the dam and when there is a heavy rainfall this water is diverted into peoples yards. Similarly, it was observed that the terrain on the settlements could be one attribute that contributes to this flooding. Given these findings, it is equally important for planners to take note of how critical it is to plan for natural hazards and the need for monitoring and evaluation of the built environment for any contraventions.

10 CONCLUSION

Planning for natural hazards is critical in reducing their effects to the lives of the people, this paper discussed what natural hazards are in the context of our study. The paper further discussed land use planning in regard to natural hazards, and the urban risk assessment and its relevance to this study was also discussed in this article. On the same note, the paper discussed and share the case experience of the situation in Lesotho regarding planning for natural hazards and whether the relevant authorities do plan for natural disasters by conducting and urban risk assessment. Ultimately, the study revealed that the relevant authorities in Maseru do not conduct urban risk assessment, hence settlements are located in high risk areas. During the transact walk it was observed that many settlements are either located at locations where they are at the risk of rockfall, whereas others are located along the flood plains. With the situation being exacerbated by poor drainage systems which is a result of unplanned development. In conclusion, this paper recommends that the Maseru Municipal and Council should engage in land use planning for natural hazards to reduce the risk of damage to infrastructure and loss of human life. Similarly, the Disaster Management Authority together with the Municipality should conduct an urban risk assessment to be able to warn people about areas which are more vulnerable to natural hazards. There is also need to improvce on the gaps in both the policy and legislative responses to the vulnerable communities and individuals whenever the need arises.

REFERENCES

[1] Obioha, E., Climate variability and food production Nexus in Lesotho, 2001–2007. *Journal of Human Ecology*, **32**(3), pp. 149–160, 2013.

[2] Letsie, M., Assessment of place vulnerability to natural hazards south-western Lesotho (Quthing and Mohales Hoek districts). PhD thesis, University of Witwatersrand, Johannesburg, 2015.

[3] Guzzetti, F., Carrara, A., Cardinali, M. & Reichenbach, P., Landslide hazard evaluation: A review of current techniques and their application in multi-scale study, Central Italy. *Geomorphology*, **31**, pp. 181–216, 1999.

[4] Moeletsi, M. & Walker, S., Agro-climatological suitability mapping for dry land maize production in Lesotho. *Theoretical and Applied Climatology*, **114**, pp. 227–236, 2013.

[5] Maro, P., Environmental change in Lesotho: An analysis of causes and consequences of land use change in the Lowland region. Department of Geography, VUB, p. 14, 2008.

[6] Burby, R., Deyle, R., Godschalk, D. & Olshanksy, R., Creating hazard resilient communities through land use planning. *Natural Hazards Rev*., **1**(2), pp. 99–106, 2000.

[7] Saunders, S. & Kilvington, M., Innovative land use planning for natural hazard risk reduction: A consequence-driven approach from New Zealand. *International Journal Disaster Risk Reduction*, **18**, pp. 244–255, 2016.

[8] Bathrellos, G., Kaymbalis, E., Skilodimou, H., Gaki-Papanastassiou, K. & Baltas, Urban flood hazard assessment in the basin of Athens Metropolitan city, Greece. *Environment Earth Science*, **75**, p. 319, 2016.
[9] Bathrellos, G. & Skilodimou, H., Geomorphic hazards and disasters. *Bull. Geol. Soc*., **39**, pp. 96–103, 2006.
[10] Bathrellos, G. & Skilodimou, D., Land use planning for natural hazards. *Land*, **8**(128), p. 4, 2019.
[11] World Bank, *Urban Risk Assessments: An Approach for Understanding Disaster and Climate Risk in Cities*, pp. 18–21, 2011.
[12] Glavovic, B., Saunders, W. & Becker, J., Land-use planning for natural hazards in New Zealand: The setting, barriers, "burning issues" and priority actions. *Nat. Hazards*, **54**, pp. 679–706, 2010.
[13] Thomas, S. & Memon, A., New Zealand government at the Crossroads? Reflections on the recent local government reforms. *Urban Policy Res*., **25**(2), pp. 171–185, 2007.
[14] Becker, J., Saunders, W., Robertson, M., Leonard, S. & Johnston, M., Issues and opportunities for land-use planning for volcanic hazards. *Aust. J. Disaster Trauma Stud*., 2010.
[15] Letsie, M. & Stefan, G., Assessment of social vulnerability to natural hazards in the mountain kingdom of Lesotho. *Mountain Research and Development*, **35**(2), pp. 115–125, 2015.
[16] World Bank, Climate risk profile: Lesotho. World Bank Group, pp. 1–36, 2021.
[17] Government of Lesotho, Disaster Management Act No. 2 of 1997. Government Printers: Maseru, 1997.
[18] Government of Lesotho, Town and Country Planning Act No. 11 of 1980. Government Printers: Maseru, 1980.
[19] Government of Lesotho, National Development Strategic Plan II 2018/19–2022/23. Government Printers: Maseru, 2018.
[20] *The Post*, It never rains but it pours, 25 Jan., 2022.

SECTION 4
THE COMMUNITY AND THE CITY

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MOTIVATION TO ACTIVE PARTICIPATION IN A COLLECTIVE: POTENTIALS OF AN EMERGING HOUSING COOPERATIVE IN FREIBURG, GERMANY

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ABSTRACT
The city of Freiburg, Germany offers a terrain for the construction of a new residential quarter with a socially motivated masterplan preferring concepts like social housing, inclusion, etc. A housing company was founded in 2019 with the target to apply and establish their future apartments. This paper explores this emerging cooperative and assesses the potential to become a successful collective on the way to the realization. The analysis is based on empirical data obtained by direct observation and active participation during the regular meetings of that group of about 70 interested households, where more and more detailed ideas for the project were developed. To find out basic interests and information on common living issues, a questionnaire was generated by community members. A majority of 52 households answered the survey. The most important results are presented. The intrinsic potential of the group to become a collective is estimated based on aspects of the theory of collective action, showing potentials and curbs. As potentials can be identified the interest in cooperative living as the central common goal and the ability of community capacity building in form of the individual economic, social and cultural contributions of the members. A clear majority declared to be willing to participate actively. But only about 20% of the participants reported detailed ideas for specific contributions. This group can be localized as the most active ones and the future cooperators of the cooperative; they belong mostly to the middle-aged generation with children. Surprisingly, the households with least time are the most active ones. It seems that the endeavor to create a surrounding of well-being for the heads of these households and especially their children (in the frame of the whole community) is the strongest motivation to become active. But that limited size of the core group could become a curb if the cooperation process will not be deepened and the multitude of tasks with different professional needs are not distributed onto more shoulders.
Keywords: cooperative living, common goals, participation, collective action, cooperators, survey.

1 INTRODUCTION

The city of Freiburg plans to construct a new residential quarter “Kleineschholz” (see Fig. 1), the inhabitants shall move until 2025. In this project, only cooperatives, private construction groups and other project promoters, who do not aim for profit maximization, are allowed to join. Building ground will be given to the best concept, not the cheapest one.

Goals for marketing are still to be formed but will certainly contain the following aspects: Projects that focus on the renters, inclusion, low-budget residential construction, maintaining the stock, ecology and climate protection, common use of spaces such as cluster-apartments and generally promotion of common welfare.

The marketing concept follows two guiding principles. At least 50% of the apartments result in subsidized housing while 100% of the ground stays public property and evades land speculations permanently through hereditary lease. Nevertheless, the roundabout 500 new apartments won’t be dirt-cheap. Due to the 50%-mark for subsidized housing, rents will still significantly stay under the rent index. Since the income limit for subsidized housing is quite high, large parts of the general public can benefit from it, making “Kleineschholz” a diverse and livable residential district.

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Figure 1: Masterplan of the future quarter “Kleineschholz” in Freiburg, Germany [1].

Living in a cooperative has a few features that may be attractive for a part of the population but also a reason not to be the favored version for others who prefer to live more in an anonymous way. In a cooperative, especially in smaller ones, inhabitants know each other and have a deeper social contact with each other. They can discuss and decide as a group what to do with common indoor and outdoor spaces, the equipment of a kitchen, a guest apartment, common gardening etc. Also, ecological and financial aspects may be part of their decisions such as the common change to a green electricity provider. Inhabitants meet regularly to do this basic work but also to celebrate the community, to clean and maintain their public spaces together etc.

A special case here is, that the future apartments and buildings have still to be planned and constructed. The cooperative can influence the procedure, that is normally outsourced and in hands of external experts, widely by themself. The design of floor plans, materials, facades, buildings and their arrangement on the site etc. could be discussed together with the (external) planners, to include and realize own visions.

One of the cooperatives that wants to apply for about 70 of these apartments, was specially founded under the name “Esche” as a registered association in 2019 [2]. The call for participation was open for everybody who was interested. In that sense it could be expected that the composition of the members represents the population but also alternatively, that those who were not interested in cooperative housing did not register and that there is already a first preselection. The first 70 households now form the core group that follows the development and organizes all necessary steps until realisation.

In 2020, a questionnaire was distributed under these 70 households to find out why they are interested in cooperative housing and living (Section 3), what their needs and wishes are (Section 4) and last but not least what kind of experience or participation they could bring in (Section 6). Responses of 52 households were received, delivering data of 83 persons acting as head of these households. Together with the children a total of 134 inhabitants results.

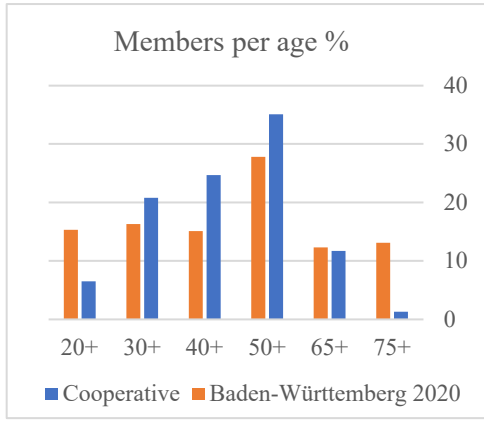
The objective of that paper is to investigate the special case of an emerging cooperative where several organisational steps to do in the future months may influence the ability to collective action strongly – to both sides. What are potentials for success where are possible curbs, what recommendations can be derived to shape the cooperative for permanent development?

The main results of the survey are presented and to discuss how far the composition of that community is representative or preselected (Section 2), what the preferred resident structure and activities are (Section 5) and if there is potential for further development given by the social and professional composition (Section 7). The key to success is the ability to

collective action, a short paragraph sketches the basics of the corresponding theory (Section 8) what will allow to assess the potential of the community to have a successful development in the future process (Section 9).

2 THE SOCIAL COMPOSITION OF THE GROUP

A comparison with statistical data shows that the composition of the group partly follows this distribution but there are also remarkable differences. Fig. 2 shows that, in regard to age, the very young ones (20+) and the very old ones (75+) are underrepresented while the middle generations 30+, 40+ and 50+ are overrepresented. In regards to the size of the desired apartment, there are only few single households but many that need space for 4 persons and more.



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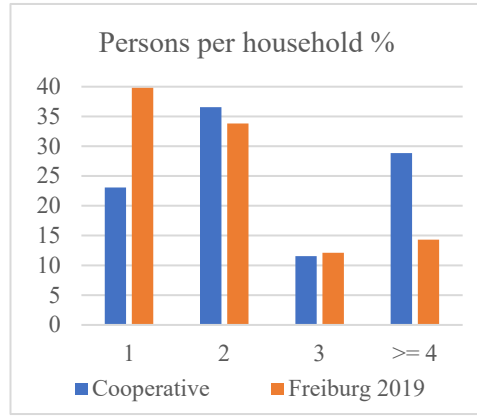

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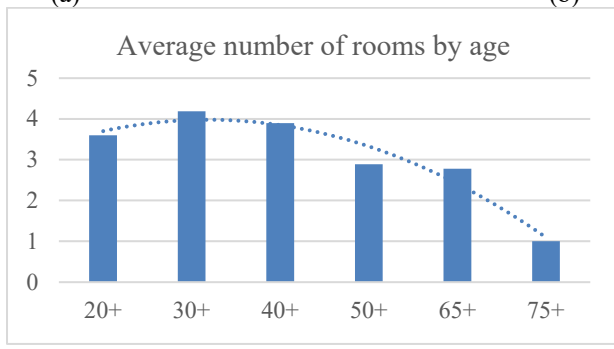

(c)

Figure 2: (a) Age of members of cooperative; (b) Number of persons per household in percentages. The graphs show a comparison with statistical data of the region of Baden-Württemberg (age [3]) and the city of Freiburg (persons per household [4]). (c) Both charts integrated show the average of the desired number of rooms sorted by age of the heads of the households.

Both circumstances seem to fit well together, the cooperative is most interesting for families with children, singles might look for their social contacts outside of a “cooperative

scale". Supplementary, families with more than four members might have problems to find sufficient and affordable apartments on the free market.

The distribution of the desired number of rooms over the age of the heads of the households confirms that the generations 30+ and 40+ have a need for bigger apartments to host their children and perhaps other family members.

In the following sections it will be investigated if households with heads 30+ and 40+ and bigger families are as representative in the cooperative only because of reasons of availability of corresponding apartments or if there are also deeper, social reasons for it.

In regard to professions, higher education (MA, BA, diploma) is in majority (Table 1), one in six has a professional training (2–3 years) but nearly one third gave no information here. 60% of the members work in service professions, nearly 10% in technical ones. While these percentages fit well with the statistical data [5], it must be noted that there is not any manufacturer or they are hidden in the third with no information.

Table 1: Professions of members of cooperative, by level (left) and by field (right).

Profession by level in %		Profession by field in %	
Higher education (MA, BA, diploma)	54.2	Service	60.2
Professional training (2–3 years)	15.7	Technical	8.4
No information	30.1	No information	31.3

It can be concluded that the common interest of living in a cooperative led already to a preselection in regard to familial situation, education and field of profession. The main correlations to the ability to collective action were found in the familial situation. Likely because of the preselection there was no notable correlation to detect in regard to education, for that reason it is not regarded furthermore.

3 INTEREST IN COOPERATIVE LIVING

In the survey it was asked for the personal interest in cooperative living without mentioning detailed reasons, the answers were given in free text. To assess that part, several categories for the interest in cooperative living were developed later, see Table 2 (ideational criteria) and Table 3 (physical criteria – building and public space). Each household could mention a category only ones, thus the maximum number of votes is 52.

Table 2: Votes in regard to interest in cooperative living (ideational criteria). The free text answers were sorted by later developed categories. Maximal total vote for 52 households is 52.

Category of interest in cooperative living (ideational criteria)	Total of votes (max. 52)
Social	46
Economical	24
Political	17
Environmental	0
Other	5

Table 2 shows that the interest in cooperative living is almost entirely based on social aspects (the community feeling) while economic arguments (affordable rents) are in second

Table 3: Votes in regard to interest in cooperative living (physical criteria – building and public space). The free text answers were sorted by later developed categories. Maximal total vote for 52 households is 52.

Category of interest in cooperative living (physical criteria – building and public space)	Total of votes (max. 52)
None	39
Ecological building – energy	5
Ecological building – material	4
Greenery and trees	3
Safe area for children	3

priority. More general political criteria (act against capitalism) play a subordinate role but are mentioned while (surprisingly) environmental arguments were not mentioned.

Table 3 confirms that the nearly exclusive interest in cooperative living is in the social range (living in a community). A cooperative that plans to construct their own future apartment building has very good chances to also realize own wishes and preferences here. An ecological building (in regard to energy and/or material) would be well possible but is at this moment out of explicit interest for the wide majority, only less than 20% have even that explicitly in mind. Similarly, (physical) design and functions of common public spaces seem not be of central importance even if gardening as a social activity is remarkably higher rated (see Section 5, Table 8).

It must be noted that the participants weren't directly asked for writing down physical aspects. Only those, who had them immediately in their mind because of personal interest, might have stated it in the survey. It can be assumed that with a direct question more detailed answers would have been given.

4 DESIRED COMMON FACILITIES

In the survey were several questions integrated where the members should assess their interest in detailed facilities on a scale 1 (lowest) to 10 (highest). For the analysis of these data, the single votes were multiplied with the corresponding number of points and the products were summed up to a final, total value. For 52 households the theoretical maximum would be $52 \times 10 = 520$.

Table 4 shows the results. Facilities where the members of the cooperative could come together, outdoor or indoor, are most common; also, a guest apartment is highly rated. Only a common sauna was not a general wish; maybe it is too intimate and not everybody is a sauna visitor.

Table 4: Total votes for several proposed detailed common facilities. Maximal total vote for 52 households would be $52 \times 10 = 520$.

Common facility	Total of votes (max. 520)
Common courtyard	443
Community room	432
Guest room	412
Roof terrace	372
Small café	304
Sauna	170

5 DESIRED RESIDENT STRUCTURE AND ACTIVITIES

Another group of questions dealt with the interest in different resident structures, again on a scale 1 (lowest) to 10 (highest). Table 5 shows that diversity in housing structures reached a high score. In the questionnaire it is explained as a mix of single apartments, flat share and families. Such a mix seems to promise a rich social exchange with members in different forms of living. But it is in contradiction to the finding that very few households want to participate in shared flats and single households are underrepresented, the majority prefers the standard forms of living as family in an own apartment. It may be that a certain exoticism plays a role or the wish not to exclude forms of living that are well accepted by the group but not as their own.

Table 5: Total votes for several proposed detailed resident structures. Maximal total vote for 52 households would be 52 × 10 = 520.

Resident structure – proposed in survey	Total of votes (max. 520)
Diversity in housing structures	388
Additional supervised residential group for elderly people	246
Additional supervised residential group for people with disabilities	158

Special supervised units for elderly and even more for disabled people did not reach a high interest. That is somewhat surprising, a cooperative is a form of living for the rest of life but the majority of 30+ to 50+ seems to concentrate more on the problems of the presence and doesn't think about their own far future and age yet.

Interesting is a more detailed view at the votes for diversity in housing structures over the size of the household and the age resp., see Table 6. The strongest wish for diversity is in the generations 50+ upwards, e.g. the households without (or adult) children; in an analogous manner the households with one or two persons. Vice versa, the households with children and in the middle generations already find enough variety in their own families.

Table 6: Votes for diversity in housing structures with a weight of 10 out of 10.

Age	%	Persons per household	%
75+	100	1	75
65+	67	2	53
50+	70	3	33
40+	33	≥4	40
30+	17		
20+	33		

Further investigations showed that there is remarkable difference in regard to the level of education. 80% of the ones with professional training weighted diversity with 10 out of 10, while only 41% of the higher educated. May be that the professional trained work directly with people, the higher educated (even if in social professions) more on a desk. That hypothesis could be confirmed with a detailed view in the single questionnaires. The direct contact to people (like nursery, educator etc.) seems to make people aware of the value of social diversity or, vice versa, the most aware ones search corresponding professions.

Supplementary, a "what else" question was asked in regard to resident structures. To assess the textual answers the most mentioned ideas were sorted in several, afterwards developed categories. For 52 households the maximum of votes is 52. Table 7 shows that about two thirds have no own/further proposals to the resident structure. About 20% saw mixed generations besides a diversity in forms of living (see Table 5) as a second, important criteria, followed by different cultural background. As already seen in Table 5, special support for elderly and inclusion of disabled were hardly mentioned as own, personal interest.

Table 7: Votes for self-proposed resident structures in "what else" questions. Maximal vote for 52 households would be 52.

Resident structure – own proposals	Total of votes (max. 52)
None	36
Mixed generations	10
Different cultural background	7
Special support for elderly	3
Disabled people	3
Other	6

Another "what else" question was asked in regard to resident activities. Table 8 shows that the majority had, besides the explicitly asked activities, no other proposals (or rather negatively formulated: no ideas). About one fourth mentioned gardening and a workshop, these are again locations outdoor or indoor where the members could meet and follow their own interests. Both probably express a certain lack of space in the present living situation to follow such activities or hobbies and an ecological mindset as well.

Table 8: Votes for self-proposed resident activities in "what else" questions. Maximal vote for 52 households would be 52.

Resident activity – own proposals	Total of votes (max. 52)
None	32
Gardening	13
Workshop	13
Studio/hobby room	5
Children playground	5
Store	4
Co-working room	3
Laundry	2
Outdoor areas to play and stay together	2
Sports room	1
Other	13

6 PARTICIPATION AND ENGAGEMENT

The households were asked if they would be willing to participate actively in the cooperative. A wide majority of 77% (Table 9) declared yes. That seems to be a very good result, however the distribution over age shows a more differentiated image. Taking the single vote 75+ as an exception, the most active ones are in the groups 30+, 40+ and 50+; remarkably are the lower percentages in the generations 20+ and 65+. The households that have least time, the families with children, are ready to contribute most. That may express that the middle-aged

generations in households with children have most power to shape their own lives and those of their children; while the 65+ with probably more time (and money) less. A lot of time alone seems not to be a source of motivation for participation, the motivation comes out of social thoughts (good surrounding for children).

Table 9: Votes for active participation in the cooperative, total values and distributed by age. Maximal vote for 52 households would be 52.

	Households willing to participate actively				
	Total	Yes		No	No information
Age	Number	Number	%	Number	Number
75+	1	1	100	0	0
65+	6	4	67	2	0
50+	20	16	80	4	0
40+	12	10	83	1	1
30+	6	5	83	1	0
20+	3	2	67	1	0
No information	4	2	50	2	0
Number	52	40		11	1
%	100	77		21	2

The question for active participation was not detailed, to answer yes is easy and corresponds to a basic feeling. The next question referred to what they could bring in detail. Table 10 shows that now the wide majority declares not to be able for concrete engagement, mostly because of lack of time. Only few persons are willing to bring in their own professional experience; in spite of the fact that they all would have a lot of professional experiences to bring in. Even under the households with experiences declare about one of five not to be willing to participate actively.

Table 10: Votes of the 52 households for different contributions in own detailed engagement. The marked 11 households could be localized as the future main cooperators of the cooperative.

Engagement for the cooperative	Total	Willing to participate actively	
		Yes	No
None	29	22	7
Own professional experience	4	4	0
Limited engagement	4	3	1
Experience with cooperative housing	6	4	2
Other	9	7	2

Again, it must be noted, that the question was a general “what else” (but under the headline participation), it was not precisely asked for what kind of detailed contributions and experiences could be brought in. It may well be, that with a corresponding question more answers would be gained.

7 POTENTIAL FOR DEVELOPMENT AND COLLECTIVE ACTION

Out of Table 10 eleven households can be localized that want to participate actively and have own professional experience or experience with cooperative housing or declare limited

engagement (because of a lack of time). These could form the core of cooperators for the present and future development of the cooperative. Table 11 delivers a more detailed information about these households, they are out of the generations 40+ and 50+ and are mainly composed of families with (more than) two children. The single persons and couples belong to 50+ and older, it may well be that they also lived in bigger families or communities before.

Table 11: Eleven households with the potential to become the future cooperators of the cooperative (see Table 10), sorted by age and number of persons per household.

Age	Number	Persons per household	Number
75+	1	1	3
65+	1	2	2
50+	3	3	1
40+	4	≥ 4	5
30+	1		
20+	0		
No information	1		

No other clear correlation to education, profession in field and level could be found – it seems, that the familial situation and the wish to create a good surrounding for the well-being of the heads of these households and their children is the dominant motivation to become active.

8 A BRIEF VIEW TO THE THEORY OF COLLECTIVE ACTION

Collective action is necessary if a smaller or bigger group of people wants to reach a common target or to maintain a common good. In case of the investigated cooperative these are the preparation and successful application for the permission to construct, realize wishes in building design and public spaces and after moving in the common maintenance of and care about the cooperative.

In such a constellation, involved people are in general interested in a positive development of the collective but might show different behaviours. The theory of collective action [6] lists three basic behavioural types, the willing punisher, the rational egoist and the conditional cooperator, see Table 12.

Table 12: The three basic behavioural types of members of a collective in regard to common action, based on Ostrom [6].

Willing punisher	Rational egoist	Conditional cooperator
Willing to punish someone in case the person does not follow the common rules of the collective.	Wants to enjoy in the advantages of the collective without taking action.	Willing to initiate collective action. Expect reciprocal contribution of others.
Wants to push members, that are on the wrong track or inactive, to the target.	Wants to gain the highest yield with lowest personal input.	Wants to pull all others to the target.
High level of contribution in case of activity.	Low level of or no contribution.	High level of contribution.

That classification already contains a few preconditions and assumptions. A conditional cooperator can only become active when the targets of the collective development are clearly defined and known to all. A punisher can only act when common rules for the behaviour in the collective are defined and established. The limits between these three groups are floating, a conditional cooperator can be highly involved in one activity and less in another one, an egoist may become active partly or also a punisher, a punisher can be a cooperator as well, instead of punishing a system of rewarding could be established.

An often-investigated question is, why do in the long history of human evolution not only the egoists survive. It seems that in the contrary in the society are always members that tend to be in one of these groups [6]; the potential conditional cooperators were assessed as between 40 and 60%. Thus, good preconditions that a newly formed collective will have a successful development. Though, in reality, a few succeed but yet a few fail.

What conditions could stabilize a collective to have a durable success? In Ostrom [7] it was recognized that trust is the central component, a conditional cooperator trusts in the other members expecting a reciprocal contribution what consequently will increase trust between all and finally the level of cooperation. Trust is also maintained through monitoring and punishing those who do not follow the norms. Fig. 3 shows the main dependencies and influences with positive or negative back coupling to collective action [8].

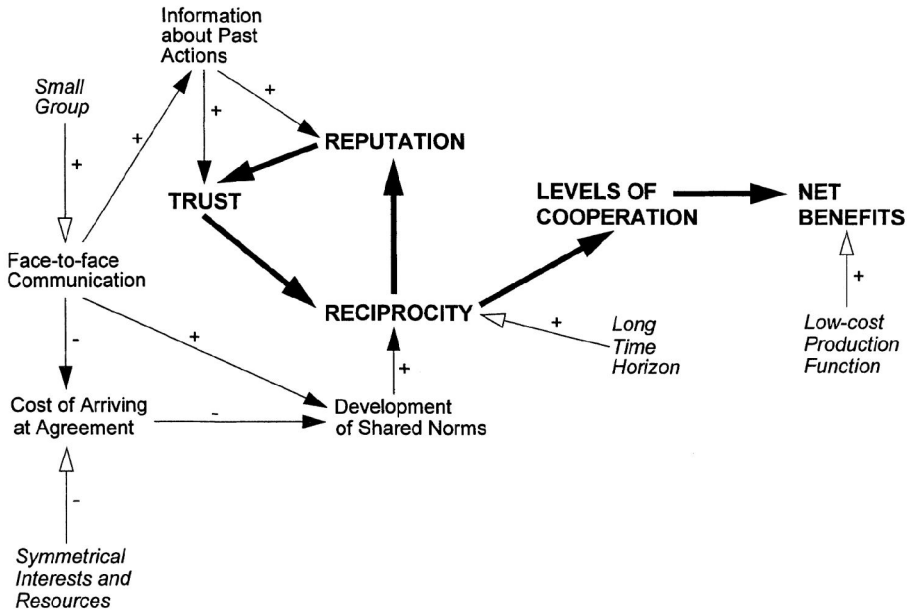

Figure 3: The main dependencies and influences with positive or negative back coupling to collective action [8].

Further aspects with positive influence were mentioned in different papers. The common targets of the collective should be of high importance for all, the collective should have a high grade of autonomy in its decisions [9], smaller groups where the members know and can observe each other are of advantage [10] as well as the existence of experienced leaders [9].

9 CONCLUSIONS

The comparison between the theory of collective action and the findings of the survey show that the cooperative has a very good potential to be successful in future development.

The final target of realizing own apartments to live together is clear and simple to understand and of central importance for all. The fact that the design of buildings and public spaces can be influenced to a good part by the group corresponds to a noticeable grade of autonomy. The collective of about 70 households is small enough that everybody knows everybody, members meet regularly and have direct, personal contact what is an ideal precondition to trust each other.

On the other hand, the group is big enough to avoid harsh conflicts on a "familial" scale, the community is able to soften conflicts. A negative aspect may be that it is hardly possible to establish a rigorous punishment system. Financial setbacks or disciplinary measures are hardly possible. Sanctions may be more on an ideational basis, verbal rebukes, disregard, exclusion from communication etc. Interviews in another cooperative [11] that moved in the apartments years ago showed that the low level of punishment was sufficient to bring rule-breaking members back on the common track.

A few active conditional cooperators are already visible but they comprise only about 20% of the group. One key element for future success will be the even distribution of upcoming work, which means that the core of conditional cooperators will need to activate other members, who declared in general to be willing to participate, for different tasks. A supplementary problem may be that there is likely a lot of corresponding professional experience but likewise no paid professional employment in minimum for the leading positions. All future conditional cooperators will have to find supplementary time out of their proper profession – the available time and energy may be limited.

Understandably, in a housing cooperative the main interest of the households is in the well-being of their own family and especially of their children. That seems to make the corresponding heads of households the most active and cooperative ones. On the other hand, they will pull the whole cooperative only as long as it corresponds to their interests on a familial scale. In case that the interests of both, family and cooperative, do not cover, there is a certain risk that diverging forces may arise in advantage to familial interests.

As long as the group has to apply for the terrain, to design the buildings and the public spaces, to realize the future physical surrounding, there is a very strong ambition not to bring the process in danger and to truly act together; conflicts and different points of view will be kept as small as possible. But, another critical point might be the moment where all is finished and ready for moving in. The big strain is gone and from then on, a different type of tasks hast to be handled – organization and maintenance of the cooperative in social and physical aspects. The punishment system loses its strongest weapon – the exclusion of a household to avoid that they move in creating a negative atmosphere for a long time. In that more relaxed atmosphere the divergent forces may reach a higher level than before and cause critical moments in further development. As a recommendation to stabilize collective action, the group and its leaders should care that all community members are involved in common activities, not only to spread the work over all shoulders but mainly to keep and increase the community feeling. That may include that group tasks have to be found or defined, especially those, that have a high potential for social exchange like common gardening, walking, sitting together, singing together etc. The collective has to re-organize itself to reach a successful continuation in their existence. Changes in the composition of the group through new occupants of apartments could also lead to changes in the collective life – newcomers have to be well integrated.

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REFERENCES

[1] Freiburg im Breisbgau, Information event on October 27, 2021. https://www.freiburg.de/pb/1787996.html. Accessed on: 20 Nov. 2021.
[2] Esche, https://esche-freiburg.de/. Accessed on: 13 Dec. 2021.
[3] Baden-Württemberg Statistisches Landesamt, Age structure: Population by age and year of birth. https://www.statistik-bw.de/BevoelkGebiet/Alter/bev_altersjahre.jsp. Accessed on: 30 Nov. 2021.
[4] Baden-Württemberg Statistisches Landesamt, Development and structure: Households by household size. https://www.statistik-bw.de/PrivHaushalte/EntwStruktur/MZreghh05.jsp. Accessed on: 30 Nov. 2021.
[5] Statistische Ämter des Bundes und der Länder, Statistical library. https://www.statistischebibliothek.de/mir/receive/BWHeft_mods_00004706. Accessed on: 30 Nov. 2021.
[6] Ostrom, E., Collective action and the evolution of social norm. *Journal of Economic Perspectives*, **14**(3), pp. 137–158, 2000.
[7] Ostrom, E., *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press: Cambridge, 1990.
[8] Ostrom, E., A behavioral approach to the rational choice theory of collective action. *The American Political Science Review*, **92**(1), pp. 1–22, 1998.
[9] Ostrom, E., Collective action and property rights for sustainable development: Understanding collective action. https://www.ifpri.org/publication/understanding-collective-action. Accessed on: 17 Dec. 2021.
[10] Poteete, A.R., Janssen, M.A. & Ostrom, E.,. *Working Together: Collective Action, The commons, and Multiple Methods in Practice*, Princeton University Press: Princeton, NJ, 2010.
[11] Wohnungseigentümergemeinschaft Saarlandstraße, Interview with several leaders of the cooperative (not published), Hamburg, 2020.

PUBLIC SPACE AND ENVIRONMENTAL BEHAVIOUR: WEEKLY MARKETS IN HAMBURG, GERMANY

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ABSTRACT

Limiting warming to 1.5°C above pre-industrial levels requires a large-scale effort to promote sustainable behaviour. The surrounding environment has a determinant influence on human behaviour and can therefore become a strategic ally towards sustainability. Using a multi-method approach in two weekly markets in Hamburg, this paper analyses how different features of the public space – like accessibility – facilitate the implementation of strategies typically aimed at the promotion of environmental behaviour – like information. The analysis shows that the two settings enable the implementation of all the revised strategies, pointing out the relevance of the public space towards more sustainable cities. Physical access in terms of public transportation and free-barrier zones played a major role facilitating the implementation of all the revised strategies while symbolic access in the form of a sophisticated atmosphere suggested a barrier for low-income groups. Visual access and opportunities for socio-cultural exchange acted together: The environment influenced behaviour through social norms-based strategies via observing what others do, role model-based strategies via sellers and information-based strategies via the spread of different types of information. In the same way, it drove subconscious decision-making throughout salience and priming-based strategies in the form of an extensive usage of signage. Regarding opportunities for economic exchange, availability-based strategies in the form of products and services played a major role, in accordance with the commercial nature of the markets. Opportunities for sensory experiences were supported by a variety of elements that created full lived-in experiences like smells and live music, which in turn might enhance the desired effect. Concerning situational features, the analysis suggests that a linear arrangement of stands provides quicker and easier access to products compared with a grid form.

Keywords: public space, environmental behaviour, behavioural change, sustainable cities, street markets.

1 INTRODUCTION

Generalized individual pro-environmental behaviour is particularly desirable in cities, which house more than half of the world's population and emit 80% of the greenhouse gasses [1]. The need to accelerate the transition is urgent but how to do it remains a puzzle. Part of the problem stems from the numerous and diverse barriers hindering environmental behaviour, which range from the lack of knowledge, individual attitudes and motivations [2] to problems dealing with the difficulty, time consuming, or cost of the behaviour [3]. Previous research suggests the combination of different strategies aimed to overcome different barriers for better outcomes [3], [4]. How to combine the different strategies and where to do it? The public space is a *neutral* scenario for communication, social learning, personal development, and various types of exchange [5]. There is where behaviours are more likely to follow the *status quo,* shaping individual decisions through automatic, unconscious cognitive processes [6] and therefore represents an opportunity to implement wide-ranging environmental strategies through social contagion.

Active engagement is one of the main functions of the public space, involving the active participation of individuals. Both, spatial arrangements and opportunities for action have been found to play an important role driving behaviour, especially concerning the interaction between individuals [7]. While the relevance of the public space as a behavioural setting has

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been established, little is still known about the potential of the public space to promote environmental behaviour.

Drawing on environmental psychology, this study adds to previous research analysing the potential of different features of the public space facilitating the implementation of strategies typically aimed at the promotion of environmental behaviour. More specifically, it identifies strategies that are already running in the public space and establishes the link with the features of the space that facilitate their implementation, showing the potential of the public space as a forum for the promotion of environmental action. Empirical material is presented from a multi-method approach of two weekly markets in Hamburg. Locations were selected based on the observation that markets are very popular places where different behavioural strategies – as *social norms* – take place, thus providing optimal conditions for the promotion of environmental action on a large scale.

This article adds to the current literature on public space and behavioural change in several ways. First, based on in-depth qualitative research, it provides a detailed understanding on the potential of the public space for the implementation of strategies typically used to promote environmental behaviour, asserting its role as a main driver towards sustainable cities. Furthermore, it provides interdisciplinary understanding of the relationship between public space, and environmental behaviour. Second, the study focuses on weekly markets, that is, popular urban settings in terms of number and human activity. In doing this, the function of the public space as a forum for action is claimed, presented as a feasible alternative that responds to the current need for the spread of environmental practices on a large scale in the fastest possible way. Furthermore, it shifts the focus from the *making* places for people to enjoy and interact to the *making* places for people to take environmental action. Third, the study provides theoretical–practical insights into the link between strategies and the features of the public space facilitating their implementation, thus providing practitioners with daily life examples that can be maximized or redirected towards sustainability.

The article begins by discussing the literature on behavioural strategies used to overcome environmental barriers and features of the space that might facilitate their implementation. This is followed by the methodology and analysis, providing valuable insights into the relationship between the surrounding environment in the markets and ongoing behavioural strategies. The last section draws conclusions and discusses the main findings.

2 STRATEGIES TO FACILITATE ENVIRONMENTAL BEHAVIOR

Individual behaviour plays a significant role in reducing greenhouse gas emissions [8] but the required behavioural shift poses major challenges as it is driven by multiple conflicting and competing internal and external factors *or barriers* [2], [3]. Internal barriers refer to factors lying within the person as knowledge or motivation [2]. External barriers or *contextual forces* include a wide range of factors as infrastructure, costs, advertising, capabilities and constraints associated with technology, and or institutional issues [3] but also availability of products and services [9] as well as social forces as norms, reputation systems and social networks [10]. Furthermore, the *how* different interventions are framed and communicated also influences decision-making processes [6]. In the reminder of this section, some of the most influential strategies aimed to overcome internal and external barriers are presented. This is followed by the presentation of features of the public space that might facilitate their implementation.

2.1 Information and knowledge

Knowledge *per se* is neither a prerequisite for environmental action [2] nor sufficient to motivate action [2], [11]. However, it is widely recognized as one of the most important factors influencing environmental action as nothing occur unless information makes individuals aware of the different opportunities for action [12]. Information influences individual perceptions, motivations, and norms [9], but also attitudes, beliefs and values [3] which in turn might influence behavioural choices. Research shows that information might be more effective when the individual has the *skill* to apply knowledge [3], [13] and it is familiar with the environmental problem and its causes [2]. In the same way, results are best when information is presented at time and place where the intended behaviour will occur and people similar to the target audience model it; if it comes from a trusted source or it is accompanied by a request for a public commitment; if it reminds people that there are norms supporting the desired behaviour, and also when it gains people's involvement and attention [3]. Information is more effective when it is accurate, credible, and targeted at the point of decision, thus suggesting concrete actions be taken according to participant's personal situation and preventing information overload [8].

2.2 Social norms

Descriptive norms refer to perceptions of which behaviours are typically performed in a given situation, placing the idea of *many people are doing this* in our mind [14]. In this line, pro-environmental behaviour is less likely to occur within a culture that propagates an unsustainable lifestyle [2]. Injunctive norms refer to perceptions of which behaviours are typically approved or disapproved [14] involving behavioural expectations that are supported by social or material sanctions [10]. People measure the rightness of their behaviour by how far away they are from the norm [15], and avoid deviance, as people tend to do what is popular as well as what is socially approved [14]. Byerly et al. [6] conducted a review dealing with the influence of different contextual variables on individual's decisions, finding out consistent effects on environmental behaviours by interventions communicating social norms.

2.3 Availability

Internal factors as attitudes are of great relevance predicting behaviours that are strongly favoured by context but their relevance declines when external factors as cost, effort, difficulty or time-consuming constrain the behaviour [3]. Moreover, some behaviours as recycling or taking public transportation can only take place if the necessary infrastructure is provided [2]. External barriers can be approached by providing clear and accurate information e.g. informing people of recycling facilities locations or by facilitating action in strictly practical terms, thus making the behaviour more convenient e.g. placing containers in close proximity to common activities to motivate action [13]. In the same way, attitudes towards organic food might improve when prices decrease [9]. This underlines the need of changes in physical, technical, and/or organizational systems aimed at the improvement in availability and quality of the desired products and services as well as the restriction and/or prohibition of unwanted actions towards successful interventions [9]. Other ways to deal with external factors include civic engagement and participation [2].

2.4 Priming and salience

Differences in the context can have a powerful effect on behaviour through automatic, unconscious processes [16]. In this way, people respond to information that is made accessible in their mind via priming through subconscious information and sensory cues, like clearly visible and numerous displays of fresh food aimed to motivate purchases towards healthy food. In the same way, people react when their attention is repeatedly drawn via salience, through reminders and message framing capturing attention, like visually attractive and friendly signs promoting energy saving placed next to light switches [6].

2.5 Role model

Individual decisions can be influenced by a careful choice of the person or *messenger* encouraging certain behaviour, as information is more effective when the person suggesting the action is perceived as similar [6]. Role model-based strategies can be also used to strengthen social norms by providing information about the expectations [6] perceptions, efficacy, and behaviour of others [9].

3 THE PUBLIC SPACE AND ACTIVE ENGAGEMENT

It is widely recognized that successful places are characterized by high levels of activity and participants, which in turn presents an opportunity for active engagement and participation. According to Max-Neef et al. [17], *participation* is a human need that could be meet through actions involving adaptability, receptiveness, solidarity, willingness, respect, rights, responsibilities, duties, work, cooperation, propose or interaction. The rest of this section covers different attributes of the public space that might facilitate the implementation of behavioural strategies typically used to promote environmental behaviour. That is, attributes of *successful* public spaces that might encourage active engagement and participation.

3.1 Accessibility

Carr et al. [18] explained the concept of accessibility from three different perspectives. *Visual accessibility* refers to what people can see and judge before taking any further steps and it is many times the first contact between an individual and a give place. A personal evaluation might include feeling of comfort, welcome and safety. The visual experience includes information about *symbolic access*, associated with *animate* (e.g. a friendly group of people) and *inanimate* (e.g. exclusive shops sending signs about the ability to pay or to meet dress norms) cues from the environment indicating the type of individuals that are welcome or excluded. Finally, *physical access* refers to the physical ability to get into and use a given place. It includes different forms of public transport making places accessible to all groups in society as well as physical elements welcoming or excluding people as slippery pavements, walls, elements inhibiting sitting or the lack of ramps for elderly and trolleys [7].

3.2 Opportunities for exchange

According to Montgomery [19], the level of activity depends on the diversity of a given place in terms of the type and number of socio-cultural and economic transactions available, which in turn might increase its *vitality* in terms of the number of people around. Montgomery [19] identifies high levels of economic activity as key for success. Ideally, a given setting includes a wide range of offers and activities (e.g. cafés, foreign grocery stores, delicatessens, and cinemas), slots of time, networks of suppliers and customers, and the building up of new

products and services [19]. Socio-cultural transactions include social interaction, communication, civil participation and different forms of social learning and personal development processes [7].

3.3 Opportunities for sensory experiences

Lived-in experiences in a given place are associated with sensation and perception processes triggered by the surrounding environment. Sensation involves input to the brain obtained by all human senses. While vision provides more information than the other senses combined, information gathered by other sensory receptors as ears, nose, and mouth create opportunities for emotionally rich experiences. Perception refers to the understanding and processing of the information received. It involves cognitive processes organizing and keeping information, interpretative processes involving associations between current and past experiences, affective processes involving feelings and evaluative processes dealing with individual values and preferences [7].

3.4 Situational features

Drawing on previous work, Carmona et al. [7] concluded that human behaviour is essentially *situational* as it is shaped by specific physical, socio-cultural and perceptual contexts. While the last two affairs were explained above, the physical environment refers to spatial arrangements that influence individual's choice by determining what people can do or not from a practical viewpoint. For example, a bench placed in a nice place offers an opportunity for a long stay, showing that the desired outcomes are more likely to occur in certain settings. In summary, individual choice might be the result of the influence of the surrounding environment in combination with a wide set of individual parameters, ranging from personal experiences to age, lifestyle or the society in which a person was raised up [7].

Based on the theoretical framework, we hypothesize that weekly markets are places that meet attributes of successful public spaces attracting people and offering opportunities for action through the implementation and ongoing of behavioural strategies.

4 METHODOLOGY

Direct observation in two weekly markets in Hamburg, Germany, was the main research method to explore the link between features of the public space and ongoing behavioural strategies. The popularity of the markets and their big size were among the main selection criteria to select the study sites, ensuring a rich exchange between individuals and space. *Isemarkt* is located in the wealthy neighbourhood of Eppendorf. According to its website [20], it is one of the largest and most beautiful markets in Germany, with about 178 market stands following an about 600m straight-line pattern. *Billstedt market* is located in the neighbourhood of Billstedt, the commercial heart of a densely populated low-income district. The street market counts around 67 market stands following a block pattern subdivided into small plots. An important difference between the two neighbourhoods is the number of migrants, which in turn influences the type of visitors to the markets. According to the German Federal Statistical Office [21], the percentage of migrants is 21.7% (4.4% from Turkey, 7.9% from Poland, 1.7% from Afghanistan) in Eppendorf and 61.2% in Billstedt (18.1% from Turkey, 14.0 from Poland, 13.5% from Afghanistan).

Direct observation was performed at irregular intervals over a period of 8 months (July 2021–February 2022). The observers spent an average of 2 hours per visit on site observing the social and physical environment. The observations focused on three main issues: the

existence of the selected characteristics of the space facilitating active engagement, the ongoing selected behavioural strategies, and their interlinkages. The information was inputted into forms produced by the author for that purpose and supported by photographic material. Participant observation included having drinks in the market's restaurants, grocery purchases and informal conversations with the sellers and market visitors. Finally, short, structured interviews were conducted with the market inspectors, buyers and sellers. These interviews provided general information about organizational issues, motivations to visit the market as well as on green selling and consumption practices.

5 ANALYSIS

The analysis is conducted in two steps: first, it identifies what features of places that might facilitate the implementation of different behavioural strategies are meet. That is, it identifies the existence of features of public spaces that might encourage action. Second, it explores how the different features facilitate the implementation of the different strategies. For a summary overview of the relationship between features of the public space and behavioural strategies along with a graphic representation, see Figs 1 and 2.

5.1 Accessibility

5.1.1 Physical access

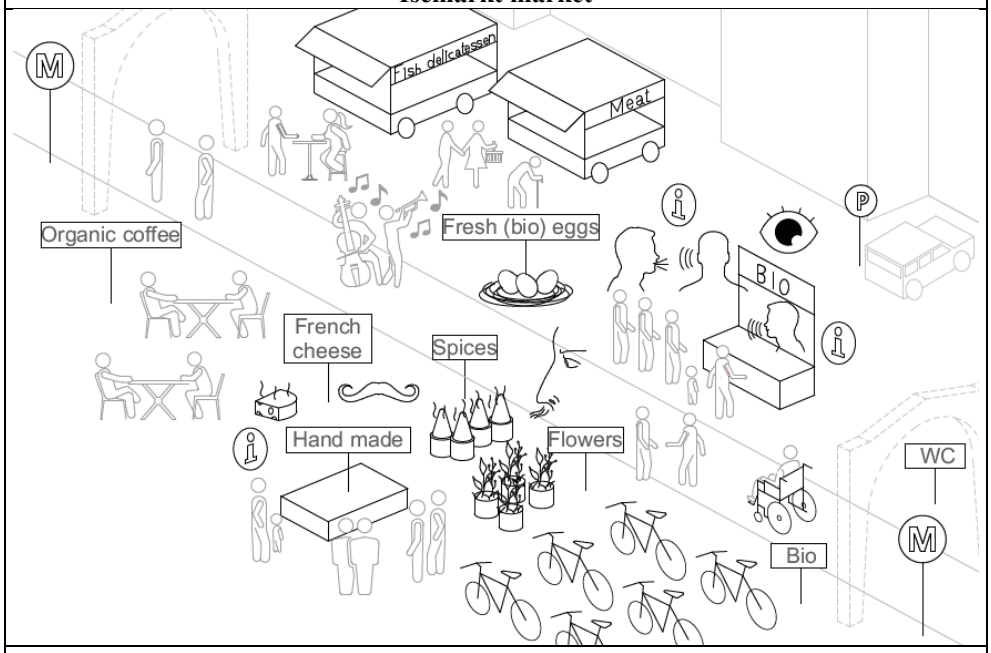
Two days a week: Tuesdays and Fridays from 8–12 am, *Isemarkt* market is placed under a bridge connecting two subway stations. As a result, there is a constant flow of people coming and going between the stations. Barrier-free subway stations enable all social groups to get into and use the place. A uniform and smooth concrete surface facilitates the mobility of persons (e.g. vehicles for persons with disabilities and supermarket trolleys) and goods. Bus stops and bike stations on every side of the market along with a central bike parking and bike racks along the street, enrich the range of environmentally friendly transport possibilities. Customers and sellers may park on both sides of the street.

Billstedt market is located within a 6-minute walk from the largest public transport station (bus and underground) in that district. Additionally, the largest shopping centre in the area is located next to the transport station, which ensures a constant flow of people moving between the station, the shopping centre and the street market. The barrier-free transport station not only ensures easy access to the place for all groups in society, but also facilitates the mobility of goods (e.g. supermarket trolleys). In the market, a significant presence of people with disabilities was observed, despite the disruption of the free flow of people by elements as uneven surfaces, light poles, bike racks, trashcans, and tree protection elements. There are several bicycle parks located in different parts of the square, facilitating access from different directions. The largest bike parking is located in a very central place and visible to everyone. Customers and sellers may park on the side streets.

5.1.2 Visual/symbolic access

Animate and inanimate cues in Isemarkt include friendly sellers – many times original growers happy to discuss about their products – and delicately decorated market stands. The numerous cafes and restaurants where people can take a break or meet someone, add to the friendly atmosphere that invites participants to take further steps. It is particularly difficult to find a place to sit down around noon, when pupils and workers take advantage of the closeness to the subway to join the market for lunchtime. The eye cannot overlook the very numerous attractive labels highlighting both the ecological quality of the different products

Isemarkt market



Features of the public space and behavioural strategies

Accessibility	**Strategies**	**Opportunities for exchange**	**Strategies**
Visual/symbolic/ physical	INFORMATION	*Economic*	AVAILABILITY
Easy access to persons and goods facilitates the implementation of all strategies	NORMS	Easy access to a wide variety of "green" and high quality products	
	AVAILABILITY		
	PRIMING		
	ROLE MODEL		
Sensory experiences		**Opportunities for exchange**	
Sight/hearing/smell/ touch/taste	INFORMATION	*Socio-cultural*	INFORMATION
Live-in experiences might optimize the influence of all implemented strategies	NORMS	Visual/written/ oral exchange	NORMS
	AVAILABILITY		AVAILABILITY
	PRIMING		PRIMING
	ROLE MODEL		ROLE MODEL

Figure 1: Public space and ongoing strategies in Isemarkt market. *(Source: Drawing by D. Guzmán under the supervision of the author, 2022.)*

(bio, local, own produced) and their high quality, including delicatessen and hand made products. That pleasant and charming atmosphere creates a feeling of comfort, welcome and safety for habitual clients, made up of the middle and upper class in the neighbourhood.

Billstedt market

Features of the public space and behavioural strategies

Accessibility	**Strategies**	**Exchange**	**Strategies**
Visual/symbolic/ physical		*Economic*	
	INFORMATION		AVAILABILITY
Easy access to persons and goods facilitates the implementation of all strategies	NORMS	Easy access to a wide variety of services and low-cost products	
	AVAILABILITY		
	PRIMING		
	ROLE MODEL		
SENSORY EXPERIENCES		**OPPORTUNITIES FOR EXCHANGE**	
Sight/hearing/smell/ touch/taste		*Socio-cultural*	
	INFORMATION	Visual/written/oral exchange	INFORMATION
Live-in experiences might optimize the influence of all implemented strategies	NORMS		NORMS
	AVAILABILITY		AVAILABILITY
	PRIMING		PRIMING
	ROLE MODEL		ROLE MODEL

Figure 2: Public space and ongoing strategies in Billstedt market. *(Source: Drawing by D. Guzmán under the supervision of the author, 2022.)*

However, it sends out a symbolic message for the type of individuals that are welcome, restricting active participation to people with the ability to pay. The eye also meets the French style iron bridge – it is the subway what is running overhead here, which in addition to beauty, assures protection against weather conditions, reinforcing the feeling of comfort and protection.

In Billstedt, *animate* cues from the environment include sellers – many times members of the settled immigrant communities in the area – and a large number of people attracted by the wide range of commercial services available, including the street market, local shops, and the shopping mall. Numerous cafes and restaurants where people can take a break or meet someone surround the market while secondary sitting in the form of wall-rings for plants provides visitors, who are not necessarily consumers with the opportunity to stay. All of it together creates a very lively atmosphere that invites others to join, mainly low-income residents, but also people from the low-income surrounding neighbourhoods. In Billstedt, numerous labels, placards and signboards marketing low-price product – especially clothing and fabrics – send a welcome symbolic sign to low-income people, in striking contrast to the situation in Isemarkt. The shops marquees surrounding the market as well as the shopping mall provide shelter against the weather if necessary.

For a summary overview of the relationship between the attribute of the public space *accessibility* and ongoing behavioural strategies, see Table 1.

Table 1: Accessibility and strategies.

<table>
<tr><th colspan="4">Accessibility</th></tr>
<tr><th colspan="2">Isemarkt</th><th colspan="2">Billstedt</th></tr>
<tr><td colspan="2"> 
</td><td colspan="2">  </td></tr>
<tr><td colspan="4">Physical access</td></tr>
<tr><td>-Public transport (Barrier-free subway stations, bus)</td><td>-Bike stations
-Car parking</td><td>-Public transport (Barrier-free subway stations, bus)</td><td>-Bike stations
-Car parking</td></tr>
<tr><td>-Smoothly surface</td><td></td><td>-Uneven surface (no problem)</td><td></td></tr>
<tr><td colspan="4">All behavioural strategies: INFORMATION, NORMS, AVAILABILITY, PRIMING, ROLE MODEL</td></tr>
<tr><td colspan="4">Visual/symbolic access</td></tr>
<tr><td>-Sellers (producers)</td><td>-Pleasant atmosphere</td><td>-Sellers (migrants)</td><td>-Lively atmosphere</td></tr>
<tr><td>-Abundant bio, delicatessen (expensive) products</td><td>-Seats (mobile carts)
-Physical shelter (bridge)</td><td>-Abundant low cost products (fabrics)</td><td>-Seats (box flowers)
-Physical shelter (shops nearby)</td></tr>
<tr><td colspan="4">All behavioural strategies: INFORMATION, NORMS, AVAILABILITY, PRIMING, ROLE MODEL</td></tr>
</table>

5.2 Opportunities for exchange

A very rich socio-cultural and economic exchange took place in the two markets. This section focuses on socio-cultural transactions dealing with visual and oral information followed by examples of economic transactions.

5.2.1 Socio-cultural exchange in Isemarkt

Visual information – written: Numerous *labels* informing about prices, offers and quality certification, *signs* providing accurate information about the producer and forms of production (e.g. family owned company since 1895 dedicated to the manufacture of caps made of wool ; free-range eggs directly from the farm), location of the farm, and product (region of origin, fruit variety). *Signboards* are providing a wide broad of information, ranging from membership in responsible farms and agricultural enterprises, including photos of good practices (e.g. chickens and pigs ranging freely) to advertising discounts on BIO products due holidays. Numerous *mobile selling carts* provide contact information as well information about products and services (e.g. Mediterranean cuisine, fish delicatessen, and homemade bread to take home and/or to eat locally). They also inform about the location of the market stand according to operation days in different locations. *Placards* provide information about the name of the market, the conditions of stay (e.g. pets, cigarettes or bikes in motion are not allowed) and opening hours. *Paper bags* are providing information on the seller and product. *Signage* provides diverse information like bicycle service or concerts.

Visual information – social norms. Here are included observations about any situation or behaviour that was notably common in the market, including specific consumer practices involving the participation of at least ten people (e.g. long queues of people and/or market stalls with many customers around). The visual assessment lead to the conclusion that environmentally friendly consumer behaviour is common as the market provides a wide variety of "green" products (e.g. free-range eggs and dairy products directly from the farm, fresh fruit, vegetables from controlled farms, regional products, products from local farmer, own harvest, self-made, vegans). All this, even if only seven of 178 market stalls hold Bio/Öko certifications, according to the information provided by the district office [22]. The market stalls "take-away" vegetarian food and "De pasta-1992", offering self-produced flour products faced problems managing the crowd.

Visual information – priming and salience: Commonly sold products in Isemarkt include a wide range of foodstuff. Here, the eye cannot overlook the very numerous and green labels highlighting both the ecological quality of the different products (bio, regional, own produced…) and their high quality, including delicatessen and hand made products. The context influences individual behaviour through unconscious process. While the high number of labels attract people's attention repeatedly, attractive cues from the environment (e.g. visually attractive labels; friendly chicken doll advertising fresh eggs) reinforce the effect on behaviour through sensory cues.

Visual information – role model: In Isemarkt, friendly sellers – many times original growers or producers – are proud of their products and happy to discuss about that with their clients. Talks include a wide range of issues such production process, cooking recipes or holidays. Talk about similar preferences or habits can contribute to strengthening ownership. In the same way, the individual decision when choosing or buying certain types of products or services is supported by comparable decisions made by people perceived as being similar. One might be tempted to assume that the sellers guide purchase decisions. The power of sellers shaping decisions however, is tempered by the wishes of the customers, as one of the

local producers in Isemarkt expressed in interview "Customers expect a huge variety of products so we have to import some of them, even if we don't want to support this. Otherwise they would go to another stand with more variety of fruits and vegetables". This example shows that the market is an articulated system in which the actors are influencing each other.

Oral information – interaction. Isemarkt provided an opportunity for interactions between different actors, including sellers, buyers, neighbours, friends, relatives, and students and workers in the area. Casual encounters between neighbours, having lunch with colleagues or meeting friends and relatives decide the frequency and duration of the interaction while the availability of toilets makes the stay easy.

Oral information – social learning and personal development. In Isemarkt, these processes occurred through observation, sensorial experiences and interaction, but also by direct learning. Direct learning occurs when a patent holder teaches potential buyers how the invented lemon squeezer works while ceramic rubs are presented and the people are gathered in a crowd by learning how to use them.

Oral information – civil participation. Three examples of civil participation were observed during the visits to the market. First, some markets stalls work with the association "foodsharing" [23], a citizens' initiative dedicated to save and distribute surplus food that would otherwise be thrown away. Second, it was noted the presence of individuals belonging to "Oma gegen Rechts" [24], an initiative of citizens founded in protest at extreme right-wing political positions whose members are mostly women in retirement or close to legal retirement age. Third, during the face-to-face interviews with randomly selected participants, one visitor asserted, "I am here to meet the distributors for my company. We only work with Bio-stands because we are a sustainable company" suggesting the existence of networks of suppliers and customers in the market.

5.2.2 Socio-cultural exchange in Billstedt

Visual information – written: Numerous *labels* informing about very low prices, *signs* providing contact information (e.g. address and phone of the seller), location of the farm, and product (e.g. region of origin, fruit variety). *Signboards* are providing a wide broad of information, ranging from political campaign (e.g. name of the candidate, email, time and place of coming events) to COVID-19 regulations. A few *mobile selling carts* provide contact information as well information about products and (home and party) services (e.g. barbecue chicken two times). *Placards* provide information about the name of the market, the conditions of stay (e.g. pets, cigarettes or bikes in motion are not allowed) opening hours as well as location of facilities and services in the area. *Stickers* feature information about diverse groups and organizations. Additionally, a wide variety of signage elements enhanced the image of business and services in the area, including banners, flags, luminous letters, fibreglass figures, large format paints, posters, and pictures on the walls.

Visual information – social norms. Like in Isemarkt, here are included observations about situations or behaviours that were notably common in the market (e.g. long queues of people and/or market stalls with at least ten customers around). The visual assessment lead to the conclusion that buying cheap is a common practice as the market is flooded by signage displaying low prices. The offer of low cost fabrics is particularly broad, including curtains, carpets and everyday clothing among many other textiles. Several market stalls offering 5€ clothing as well as the "barbecue chicken" mobile cart, faced problems managing the crowd. The visibility of "green" products (bio, regional, own produced…) was notoriously poor. According to the information received from the district office, there is no information available on Bio/Öko certified products [25].

Visual information – priming and salience: Commonly sold products in Billstedt include a wide range of classical products as fruits, vegetables and households goods. Here, the eye cannot overlook the very numerous inanimate cues from the environment in form of labels, placards and signboards marketing low-price products, especially clothing and fabrics, but also trinkets and highly demanded products as medical masks. The low prices are displayed on placards of all sizes and materials. The quality of the signs varies greatly, ranging from colourful signs in vinyl, to simple carton with the price – in very big letters – written by hand. While the high number of low price labels and placards attract people's attention repeatedly, visually attractive cues from the environment (e.g. mannequins modelling clothes) act through sensory experiences.

Visual information – role model: In Billstedt, many of the sellers belong to the migrant communities settled in the area. Members of different communities performed different actions (e.g., a group of head veiled women rummaged a pile of low cost clothes while a long line of coloured people waited for barbecue chicken), in a mutually reinforcing and supportive action. In the same way, some food shops are particularly attractive to specific ethnic groups, suggesting preserved traditions, and therefore, specific eating habits. The influence of people perceived as similar when performing action might be particularly strong when the difference between cultures is remarkable. Here, it is worth saying that different sellers reacted differently to the observers. One seller offered a fruit short after having initiated conversation while others reacted swiftly and negatively to the photos, also when taken from far away, suggesting differences in the way they interact with the territory and strangers.

Oral information – interaction. In Billstedt, sellers talking and spending time with their customers even when they should sell something, created a friendly atmosphere and suggested networks of suppliers and customers. Lively encounters also occurred among neighbours, friends, and relatives, who took advantage of numerous flower boxes for a long stay. The great variety of shops and services in the area – besides the proximity with the shopping centre – attracted a large number of people. Some are sitting in one of the numerous established restaurants in the area while others are simply observing and enjoying the excitement of the place.

Oral information – social learning and personal development. In Billstedt, social learning occurred through the observation and perception of what others do, sensorial experiences, and interaction.

Oral information – civil participation. Forms of civil participation included signboards and stickers supporting different political orientations and ideologies.

5.2.3 Economic exchange: Isemarkt and Billstedt

Convenience/availability. The two settings facilitated the access to a wide variety of products and services in one single place, helping to overcome external factors hindering action as effort, difficulty, or time constraints. However, there were major differences between the products and services offered by the two markets, and thus differences in consumer behaviour practices and associated environmental impacts.

In *Isemarkt*, the trading of foodstuff is the most important economic activity, among which outstand products intended to be environmentally friendly (as mentioned earlier, only seven stalls hold Bio/Öko certifications) and delicatessen. There is also a wide range of classical products as household goods and textiles. Mobile carts offer the opportunity to eat sitting down or carryout. The food is varied, ranging from sausages and fries to vegan options, homemade, vegetarian, or Vietnamese food.

Billstedt also offers a wide range of classical products, including food products as fruits and vegetables or household goods. In striking contrast to the situation in Isemarkt, the offer of both environmentally friendly products and delicatessen is very limited. Rather, low-cost products abound, mainly textiles as curtains, bed sheets, rugs, carpets and everyday clothing like dresses, socks, and jackets. All of this despite the interviews indicated that one of the main reasons to visit the market is to get fresh and healthy food for the family. The location of the market in the commercial heart of that area of the city facilitates access to a wide offer of services, including numerous well-established restaurants. Consequently, the cooking offered by the market is limited to take-out food, including sausages and fries, but also offers hot sahlep, a Turkish drink made from the roots of several species of orchids. Table 2 shows an overview of the products and services offered by the two markets.

Differences in consumption practices show the potential of availability-based strategies to guide individual decisions and achieve the desired outcome. For a summary overview of the relationship between the attribute of the public space *opportunities for exchange* and ongoing behavioural strategies, see Table 3.

Table 2: Availability of products and services.

Availability of products and services		
	Isemarkt	Billstedt
Classical products	Fruits, vegetables, meat, fish, dairy products, spices, household goods, flowers, textiles, jewellery, sweets, candles, items for pets, pasta, porcelain, glass cups, etc.	Fruits, vegetables, meat, fish, dairy products, spices, household goods, flowers, textiles, jewellery, sweets, items for pets, decoration, tools, toys, trinkets, etc.
Specialities/delicatessen; highlights	homemade food, delicatessen, grill specialities, rice burger, dried fruit, leather, forest fruit juice in glass, bush meat, variety of vegetables, liver loaf, handmade, organic clothing	
Bio/Öko certifications	Fruits and vegetables 3 stands; meat products 2 stands; bakery 2 stands	
International flavour (products and culinary offer)	French, Italian, Portuguese, Vietnamese	Turkish, Polish, Austrian
Services (in the market and surroundings)		Restaurants, cafes, hairdressers, mobile phone shops, banks, pharmacies, mail service, electronic products, health services, supermarkets, fabric care, tobacco, lottery, gym; Shopping centre offering multiple products and services

Table 3: Opportunities for exchange and Strategies.

Opportunities for exchange	
Isemarkt	**Billstedt**
	
Socio-cultural exchange	
General/accurate information about products, sellers, services, various (concerts), etc.	General/accurate information about products, sellers, services, various (political), etc.
INFORMATION Visual/written information	**INFORMATION** Visual/written information
Numerous people consuming expensive "green" and delicatessen products (mainly foodstuffs)	Numerous people consuming low-cost products (foodstuffs along many textile products)
SOCIAL NORMS Visual information	**SOCIAL NORMS** Visual information
Numerous visually attractive and well-designed labels highlighting the "green" and high quality of the products	Numerous visually and not always well-designed labels displaying low prices
PRIMING AND SALIENCE Visual information	**PRIMING AND SALIENCE** Visual information
Sellers (original growers) and customers with similar look and consumption practices	Sellers (look like migrants) and customers with similar look and consumption practices
ROLE MODEL Visual information	**ROLE MODEL** Visual information
Interactions involving sellers, customers, local neighbours, friends, relatives, students and workers in the area	Interactions involving sellers, customers, local and district neighbours, friends, relatives
Social learning and personal development through interaction, observation, live-in experiences and HOW to do it practices	Social learning and personal development through interaction, observation, and live-in experiences
Civil participation in the form of networks (suppliers, customers, civil organizations), and political demonstrations	Civil participation in the form of signage and stickers supporting different political and ideological orientations
INFORMATION Oral/visual information	**INFORMATION** Oral/visual information
Economic exchange	
Easy access to a wide variety of products, outstanding "green" and high quality products	Easy access to a wide variety of products (wide offer of low-cost fabrics) and services
AVAILABILITY	**AVAILABILITY**

5.3 Opportunities for sensory experiences

The presence of numerous individuals who are cheerful and relaxed together with a very colourful decoration create a truly lively and festive atmosphere in the two settings. The analysis shows that all the senses are stimulated when visiting the market, creating opportunities for emotionally rich experiences through sensation and perception processes, which in turn might optimize the impact of planned interventions.

Looking at *Isemarkt* is a very rewarding experience: from visually attractive and elegantly designed market stalls to carefully selected products (e.g. bio, handmade) nicely packaged, jewellery, ceramics and flowers. The atmosphere changes throughout the year. Colourful fruits, vegetables and flowers are especially evident in summer, while Christmas decoration like candles are the focus during the winter season. Visually attractive and carefully designed mobile selling carts add to the fancy atmosphere. Here, the captured scene includes the stamp of an elegant couple of deer and boar promoting grill specialties in competition with a sexy mermaid advertising fish delicatessen.

Rhythm and music from street musicians (clarinet, accordion, contrabass and guitars together with the knife sharpener using tools to play "drums") fill the air with joy. The aromatic experience includes sweet (flowers, crepes), stimulating (cheese, spices, coffee) and strong (fish, meat) smells, while curiosity leads a willing hand to touch an exotic fruit or participate of the tasting cheese experience.

The location of the *Billstedt* market in the commercial heartland of that part of the city leads to duplication of efforts to catch people's attention. Different products and services are promoted via luminous letters, signboards, flags, stickers, posters and pictures, placards, information boards and signs in different sizes and colours, predominantly yellow and red. Efforts to attract the visual attention of visitors include shop windows exhibiting diverse products – like a box of vitamin supplements in big format – and fibreglass figures – like a big ear advertising hearing devices or clothes dressed on female mannequins. Colourful fruits and vegetables in combination with playful products as costumes and wigs as well as trinkets and toys contribute to create a lively and joyful atmosphere. During the visit, one seller was singing when he was selling to customers, the hand took the offered fruit to pre-test and the nose announced the proximity of the sahlep stand, enriching the sensorial experience. For a summary overview of the relationship between the attribute of the public space *opportunities for sensory experiences* and ongoing behavioural strategies, see Table 4.

5.4 Situational features

In Isemarkt, about 178 markets stands follow an about 600 m path sheltered by a bridge with a subway station at each end. The market stands run along both sides of the approximately 5 m wide road, allowing a front, left and right view. It is a pedestrian road, as two large parallel streets on both sides of the bridge are used to transport the goods. There are not evident spatial arrangements preventing social or economic activities. Indeed, many visitors shop while moving from one subway station to the other, facilitating an overview of the different activities in the place and thereby facilitating the success of planned interventions.

Billstedt market is based in a central square, laid out on a grid system. In the square, there are elements that could disrupt the free flow of people as structures for lighting, bike rack, trashcans, wood frames for the care of trees, and flower boxes, in addition to a uniform walking surface. Nevertheless, people in wheelchairs are regular visitors. Moreover, the

Table 4: Opportunities for sensory experiences, situational features and strategies.

Opportunities for sensory experiences and situational features	
Isemarkt	**Billstedt**
	
Sensory experiences	
-Sight: a wide range of visual stimuli (signage, colours, figures made of cardboard, etc.)	-Sight: a wide range of visual stimuli (signage, colours, figures made of fiberglass, etc.)
-Hearing: Street musicians (clarinet, accordion, contrabass, guitars) and enthusiastic sellers	-Hearing: Enthusiastic sellers
-Smell: sweet (flowers, crepe), stimulating (cheese, spices, coffee) and strong (fish, meat)	-Smell: sweet (flowers), stimulating (cheese, spices, sahlep) and strong (fish, meat)
-Touch: exotic fruit	-Touch: clothes, fabrics
-Taste: cheese pre-test	-Taste: fruits pre-test
All behavioural strategies: **INFORMATION, NORMS, AVAILABILITY, PRIMING, ROLE MODEL**	
Situational features	
The street pattern allows a front, left and right view	The grid pattern offers many different ways to go, see and experience
All behavioural strategies: **INFORMATION, NORMS, AVAILABILITY, PRIMING, ROLE MODEL**	Behavioural strategies: path-dependent

flower boxes facilitated stay conditions, suggesting that the spatial arrangements do not constrain social and economic activities. However, a grid system enables individuals to find their way in the market, limiting the influence of potential interventions to the areas and stands visited.

For a summary overview of the relationship between *situational features* and ongoing behavioural strategies, see Table 4.

The analysis shows clear evidence that the two weekly markets studied here are places with a high number of activities involving the active participation of individuals. Furthermore, the two settings enabled the implementation of all the revised behavioural strategies, pointing out the potential of the public space to influence individual behaviour. The results are further discussed in the next section.

For a graphical overview of the ongoing behavioural strategies in the markets and related features of the public space, see Figs 1 and 2.

6 CONCLUSIONS AND DISCUSSION

This research explored the potential of the public space as a forum for the promotion of environmental action. For that, the study investigated the relationship between four features of the public space (accessibility, opportunities for exchange, opportunities for sensory experiences and situational features) and five strategies typically used for the promotion of environmental behaviour (information, social norms, availability, priming and salience, and role model). The first conclusion of the analysis is that under certain conditions, the public space becomes an optimal scenario for the implementation of strategies that could be used to encourage environmental behaviour. The analysis showed clear evidence that all the strategies studied are already running in the two weekly markets. These findings suggest that researchers and practitioners dealing with behavioural change should recognize the role of the public space – street markets and corresponding social dynamics in particular – as a forum for action and behavioural setting, favouring conditions to use it for the spread of environmental practices on a large scale.

Second, regarding features of the space, the analysis shows that easy access to the place in the form of free-barrier areas, public and private transport as well as friendly pavements facilitated the movement of goods and people into, out of and around the markets, pointing out the *physical accessibility* feature as a pre-condition for the implementation of all the strategies. *Visual and symbolic access* sent mixed signals about whom and what to buy through cues from the environment. Radically different social atmospheres and products (green and high quality products in a refined atmosphere vs. low-cost products in a warm but simple atmosphere) symbolically closed off access to people who feel comfortable in that particular atmosphere, like certain items and are able to pay for them. This draws attention to the importance of encouraging the visit to the site of action by creating an inclusive atmosphere for all sectors of society, particularly avoiding the association between green products and very high prices (an issue that needs to be solved in practice first). Once in the market, the individual is exposed to massive *opportunities for exchange,* which in turn facilitated the implementation of all the strategies. Sociocultural exchange included a vast amount of visual, written, and oral information in the form of signage and different forms of interaction and social behaviour, including direct learning experiences and civil participation. For its part, economic exchange included a vast number of buy and sell activities, in line with the economic nature of the street markets. The wealth of information answering whom, what, how and where questions about products and services in combination with easy and fast access to them, might facilitate action by overcoming effort, difficulty or time constraints but also influencing perceptions, motivations, attitudes, beliefs and values. *Opportunities for sensory experiences* included pleasant live-in experiences that stimulated all five senses, which in turn might reinforce the influence of the context driving action. The analysis of *situational features* dealing with the influence of spatial arrangements guiding action highlighted the importance of a physical arrangement that facilitates long stays and ensures the continuous exposure of the participant to opportunities for action. Possibilities for sitting together with toilets and weather protection facilitated long stays. It is worth saying that primary sitting was essentially restricted to restaurants, which were very popular with customers in both settings. Secondary sitting like flower boxes, stairways and sidewalks were very popular, probably because it enabled visitors to enjoy the place with or without the need to consume. Regarding exposure, the analysis shows that a street pattern that allows a front, left and right view facilitates the continued exposure of the participant to opportunities for action.

Third, all the revised strategies deal in one way or another with different types of information, including visual, written, oral, but also sensory information, leading to the

conclusion that information-based strategies play a key role promoting action, in line with previous research. The findings complement the existing literature in shedding light on visual information as the most relevant strategy influencing action in the markets, places largely associated with face-to-face communication. Visual information is linked to the very numerous printed signage. It is also closely linked to social norms-based strategies showing what other people do, priming and salience-based strategies attracting the attention of the consumer repeatedly through a wide use of signage and items, and role model-based strategies guiding and reinforcing individual decisions while observing people perceived as similar performing certain behaviour. Additionally, people have visual access to all the products offered, influencing availability-based strategies. Visual information is also a main component when creating live-in experiences.

A fourth result is a by-product of the study: the analysis reveals significant differences in the type, quality and price of products offered in the two settings. The type of products ranges from supplies needed for survival to entertainment products. Their quality ranges from bio label to unknown origin, while their cost ranges from relatively very expensive (mostly environmentally friendly products) to very low (mostly clothing and fabrics). In line with the main theoretical argumentation of this paper, this shows that the influence of the environment can pull in opposite directions. For instance, placing the sell and purchase decision between green, high quality and expensive products and low-cost, dubious quality products. All efforts should therefore focus on directing the different strategies toward the desired results.

One final observation is that in one of the settings, sellers used use words as “fresh” and “supervised production” as well as the green colour to highlight the environmentally friendly quality of their products. All that, when only seven of 178 stands hold bio certifications, drawing attention to the need for a clear, fair and efficient classification system of environmentally friendly products.

Being exploratory in nature, this study focused on a limited selection of street markets, limiting the generalizability of the empirical results. Further studies might want to focus on larger samples and more standardized forms of measurement to explore further the conditions under which those places become spaces suited to the spread of sustainable behaviour. In this line, further research should examine current (none) environmental practices performed by clients and sellers as well as identify the most effective practices to be performed in accordance with the sociodemographic characteristics of the participants and spatial conditions. Furthermore, the potential of the public space reinforcing community resilience is a fruitful area for research: weekly markets provided easy and fast access to medical mask during the COVID-19 pandemic.

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REFERENCES

[1] Short, J. R. & Farmer, A., Cities and climate change. *Earth*, **2**(4), pp. 1038–1045, 2021.
[2] Kollmuss, A. & Agyeman, J., Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, **8**(3), pp. 239–260, 2002.
[3] Stern, P., Toward a coherent theory of environmentally significant behavior. *Journal of Social Issues*, **56**(3), pp. 407–424, 2000.

[4] Abrahamse, W., Steg, L., Vlek, C. & Rothengatter, T., A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology*, **25**(3), pp. 273–291, 2005.
[5] Loukaitou-Sideris, A. & Banerjee, T., *Urban Design Downtown: Poetics and Politics of Form*, University of California Press, 1998.
[6] Byerly, H. et al., Nudging pro-environmental behavior: Evidence and opportunities. *Frontiers in Ecology and the Environment*, **16**(3), pp. 159–168, 2018.
[7] Carmona, M., Heath, T., Oc, T. & Tiesdell, S., Public spaces. Urban spaces. The Dimension of Urban Design, Italy, 2010.
[8] De Coninck, H. et al., Strengthening and implementing the global response. *Global warming of 1.5°C: Summary for Policy Makers*, IPCC-The Intergovernmental Panel on Climate Change, pp. 313–443. 2018.
[9] Steg, L. & Vlek, C., Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, **29**(3), pp. 309–317, 2009.
[10] Simpson, B. & Willer, R., Beyond altruism: Sociological foundations of cooperation and prosocial behavior. *Annual Review of Sociology*, **41**(1), pp. 43–63, 2015.
[11] Trenberth, K.E., Marquis, M. & Zebiak, S., The vital need for a climate information system. *Nature Climate Change*, **6**(12), pp. 1057–1059, 2016.
[12] Stern, P.C., Information, incentives, and proenvironmental consumer behavior. *Journal of Consumer Policy*, **22**(4), pp. 461–478, 1999.
[13] McKenzie-Mohr, D., Nemiroff, L.S., Beers, L. & Desmarais, S., Determinants of responsible environmental behavior. *Journal of Social Issues*, **51**(4), pp. 139–156, 1995.
[14] Cialdini, R.B., Crafting normative messages to protect the environment. *Current Directions in Psychological Science*, **12**(4), pp. 105–109, 2003.
[15] Schultz, P.W., Nolan, J.M., Cialdini, R.B., Goldstein, N.J. & Griskevicius, V., The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, **18**(5), pp. 429–434, 2007.
[16] Dolan, P., Elliott, A., Metcalfe, R. & Vlaev, I., Influencing financial behavior: From changing minds to changing contexts. *Journal of Behavioral Finance*, **13**(2), pp. 126–142, 2012.
[17] Max-Neef, M., Elizalde, A., Hopenhayn, M. & Sears, R.V., *Development Dialogue*, *1*, p. 140, 1989.
[18] Carr, S., Stephen, C., Francis, M., Rivlin, L.G. & Stone, A.M., *Public Space*, Cambridge University Press, 1992.
[19] Montgomery, J., Making a city: Urbanity, vitality and urban design. *Journal of Urban Design*, **3**(1), pp. 93–116, 1998.
[20] Hamburg, Wochenmarkt Eimsbüttel, Isemarkt. https://www.hamburg.de/wochenmarkt-eimsbuettel/3888304/wochenmarkt-isestrasse/. Accessed on: 1 Sep. 2022.
[21] Berichte, S., Bevölkerung mit Migrationshintergrund in den Hamburger Stadtteilen 2021. Statistisches Amt für Hamburg und Schleswig-Holstein, 2021.
[22] Bezirksamt Eimsbüttel, Fachamt Verbraucherschutz, Gewerbe und Umwelt. Abteilung für Veranstaltungs- und Marktrecht, 2022.
[23] Foodsharing, foodsharing.de. Accessed on: 1 Sep. 2022.
[24] Omas gegen rechts (support). http://www.omasgegenrechts.de/. Accessed on: 1 Sep. 2022.
[25] Bezirksamt Hamburg-Mitte, Fachamt Verbraucherschutz, Gewerbe und Umwelt. Abteilung für Veranstaltungs- und Marktrecht, 2022.

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LOCAL CREATIVES SUSTAINING SMALL COMMUNITIES

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ABSTRACT

"Măiastra" (also known as "Magic Birds") identifies itself as a multidisciplinary program for contemporary art and design. It was initially built around the exploration and the influence upon contemporary creation and lifestyle of the traditional "Romanian Blouse", perceived as an identity symbol, as well as an art piece, and the ancestral practices and crafts developed throughout. It was later established as a platform that aims to explore the past and future of cultural identity, with focus on art and design, both Romanian and international. This paper analyses the influence that the "Măiastra" program had alongside Romanian craftsmanship, sustainable living, as well as the emerging artists and designers involved in the process. The program's innovation lays in the impact it had on the sustainable creation produced in Romania, whilst showcasing collaborative and multidisciplinary contemporary art and design practices, which highlights the ongoing tradition – future cycle. The projects and the exhibitions produced over the years came to support artists and designers who found their creative resources in ancestral symbolism, local materials and crafts, only to innovatively transpose them in the present, through various artworks, design objects, installations, sustainable house projects or sustainable creative processes. This paper introduces three representative projects, found at the intersection of sustainability and local culture, art and design, science and technology, all taking the form of collaborative exhibitions. Supporting local art, design and crafts leads to sustaining local communities, the ground root that could potentially prevent migration to the bigger cities, perhaps even promote reverse migration.

Keywords: crafts, sustainable living, multidisciplinary, sustainable houses, Romania, craftsmanship.

1 INTRODUCTION

A common thread throughout my research endeavours has been my grounded interest for heritage, inherited traditions that are preserved and transmitted amidst generations and different world cultures. It started with a growing interest for my own culture, only to continuously looking to extend to as many others with time. Because to sustain legacy not only in the region, but worldwide, both as the basis for the local economies and heritage preservation, it is necessary to seek alternatives to engage older craftsmen while attracting younger generations and introduce these types of collaborations internationally. It is important to create opportunities that enables the transfer of knowledge and know-how, through multidisciplinary initiatives meant to showcase these endeavours, such as "Măiastra" ("Magic Birds") program, initiated in 2013 by Galateca art gallery in Bucharest, Romania. It was one of the first programs built to inspire the new generations of creators, towards discovering and recontextualizing traditional crafts, symbols, and ancestral practices.

I invited Andreea Sandu, the founder and coordinator of Galateca art gallery to be a part of this paper and to convey her journey, as we share a common interest for heritage, as well as the desire to bring a contribution to its preservation. Together with a team of artists, architects, anthropologists, and communication experts she started "Măiastra" program, back in 2013, by curating the first exhibition in a contemporary art gallery focusing on "IA" or the "Romanian Blouse" perceived as a symbol of Romanian identity. The first exhibition of the program, entitled "Măiastra: The Untold Story of the Romanian Blouse", showcased a selection of museum standard traditional blouses, presented in the form of an art installation.

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The project became the focal point for a newly developing platform that had as aim the exploration of the past and future, with focus on art and design, both Romanian and international. It traced new aesthetics for the approach towards multidisciplinary installations and contemporary projects that recontextualize the crafts in Romania.

Craftsmanship is rooted within the rural, ancestral times, rising as a testament of authenticity throughout the years. Historically, crafts were associated with a bucolic way of living and a rural habitat. Consequently, craftsmanship takes place in a suitable environment, following a natural rhythm of nature and community, part of a traditional maker's lifestyle. Crafts are part of a whole, a system, inside which each element is interconnected, and one could not survive and strive without the other, and these believes, and practices have been proven to be effective for generations. Their preservation and perpetuation are essential in transmitting to future generations ones' cultural identity. And although hard to achieve in the present, these practices and believes are being explored by displaced people like myself all around the world in our strive to evoke the homeland and a sense of belonging, or to recreate our familiar. Together with sustained efforts from creatives and cultural initiators like Andreea Sandu, who are taking the lead internally, our actions are gradually finding a voice.

The aim of this research is to introduce examples of notable initiatives in the field of art and design that come in support of our cultural heritage. Presented as a case study, one such example is "Măiastra" ("Magic Birds"), the multidisciplinary program for contemporary art and design. The program not only offered a voice to local and international creatives who aimed to collaborate with local makers, using ancestral crafts, materials, practices or believes, but also understood quickly that the projects introduced had the potential to become an instrument that could possibly lead to real changes within the local outlook. Starting with an archival research in order to set the program's structure, several field explorations followed, in order to discover local creatives and makers that would become part of the program. An ongoing research preceding each edition, helped in tracing the themes and participants' selection, as well as the overall layout. The program raised visibility and awareness towards local crafts, practices and believes, having both a physical and a virtual configuration, therefore a qualitative analyses was considered as the best approach. Throughout the creative communities and not limited to those, elements of material and immaterial culture has been increasingly adopted, being implemented within an array of multidisciplinary art and design projects. The population at large started to integrate parts of the traditional costume (precisely the "Romanian Blouse") more and more often into their daily attires, leading to an increased interest for traditional items, produced by local makers. Such examples include the renowned potter from Maramures, Daniel Les, Virginia Linul from Bistrita Nasaud, working together with over 50 women based in rural settlements around the region, or Dana Dobrai, a weaver from Maramures County, Romania.

2 METHODOLOGY

This research takes a qualitative approach to explore case studies concerning multidisciplinary art and design projects, having as focus, collaborations between artists, designers, and local makers, in an initiative to sustaining small communities. As such, it introduces three case studies, within different spheres, like crafts, design, and arts, all gathered under one umbrella entitled "Măiastra" (also denominated as "Magic Birds"). A multidisciplinary program built as a showcasing platform, as well as a tool for the creatives involved to raise awareness and therefore gather likeminded people, from different generations, who share the same interests towards heritage, sustainable living, and authentic values. The founder of the program, Andreea Sandu, together with her team, started with an archival research in order to trace the program's outline, in respect to ancestral values,

followed by recurring field studies, in order to discover and select creatives and makers that would become part of this journey. An ongoing research preceding each edition of the program helped in tracing the themes and participants' selection, as well as the configuration, overall layout and communication strategy. For each edition of the program, the creatives selected shared the same voice, as well as a common approach towards recontextualizing heritage within contemporary projects, which was concluded through individual interviews. The results of their work, lead to an increased awareness towards heritage amongst the community and together with the development of the digital platform it reached a wider audience. Through their creative endeavours, they have managed to sustain local makers, initiating more lucrative opportunities, showcasing their work throughout communities and online, hence contributing to the economic development.

Consequently, "Măiastra" program positions itself as a showcasing platform for multidisciplinary creatives looking to find and share their ideas in order to potentially trace a new paradigm that conveys the intersection of sustainability and local culture, art, design, science, and technology.

3 "MĂIASTRA" AS A MULTIDISCIPLINARY PROGRAM

The inspiration for "Măiastra" ("Magic Birds") denomination came from Constantin Brâncuși, the renown Romanian artist who once said that borrowed clothes have a different smell and they never accurately match your own body, or being. I firmly believe one's distinctiveness is rarely disconnected (on different levels) from the heritage and ancestral values. Inspired by the Romanian identity, the "Magic Birds" program bears the name of one of Brâncuși's iconic sculptures and it represents the first identity platform that brought the traditional back into the public eye in Romania.

Andreea Sandu, founder, curator and coordinator of the program, started this journey 9 years ago, a journey that explores the influences of traditional crafts and art, and the ancestral believes upon the contemporary art scene, artists, designers, architecture and lifestyle. When initiated, back in 2013, "Măiastra: The Untold Story of the Romanian Blouse" program, focused on "IA" or the "Romanian Blouse" as a symbol of Romanian identity. The popular "Romanian blouse" represents the upper part of the traditional costume and can be catalogued in two categories, a daily (more casual), generally used for work, and a second type, more complex, dedicated to a different array of holidays. The second is enhanced by heavy embellishments, having been used for ceremonies, religious holidays, and other types of community celebrations. Despite the end use, the "Romanian blouse" remains a constant garment that accompanied women throughout their life since early times. The traditional "Romanian blouse" is the seductive conclusion of centuries of craftsmanship and chromatic imagination. The installation of blouses was accompanied by an array of archival photographs of her excellency, Queen Marie of Romania, wearing the traditional Romanian costume, as well as a series of 35 mm black and white negative strips featuring images taken in Romania by Beryl de Zoete in the mid to late 1930s. de Zoete photographed folk dance and costumes worn by villagers in villages between Bucovina, Transylvania and Oltenia.

The negatives were donated to the Horniman Museum in 1962 after de Zoete's death and were first printed up and shown to the public in 2000 at the University of Brighton [1]. Amongst the partners of the program, we can mention distinguished institutions, such as Horniman Museum and Gardens (London, UK), National Museum of the Romanian Peasant (Bucharest, Romania), Astra Museum (Sibiu, Romania), Bucovina Museum (Suceava, Romania) and Mircea Dinescu collection (Bucharest, Romania), amidst others. The logo of the program was inspired by the figurative representation on traditional blouses of "Măiastra" bird, a symbolic or allegorical bird from Romanian mythology, with a royal rank. Created by

the Romanian architect, Andrei Găleata, the logo followed the idea of line representation of "Măiastra" bird, alongside the column and the magic eye, all common symbols in Romanian heritage (Fig. 3).

Figure 1: Image from Galateca gallery archive "Măiastra: The Untold Story of the Romanian Blouse" exhibition. All rights reserved, 2013.

Figure 2: Image from Galateca gallery archive "Măiastra: The Untold Story of the Romanian Blouse" exhibition. All rights reserved, 2013.

Figure 3: Măiastra logo, created by architect Andrei Găleată for Galateca gallery.

4 CASE STUDIES

4.1 "Măiastra: Visual fairies" exhibition and identity platform

The 2016 edition of "Măiastra: Virtual fairies" (Fig. 4) project marks an important step in the program's evolution, moving further from the traditional Romanian blouse to taking

Figure 4: Image from Galateca gallery archive, all rights reserved, 2016 "Măiastra: Sânziene virtuale" exhibition, part of the show's video mapping.

inspiration from crafts and ancestral practices and beliefs, populated by an eclectic blend of the traditional and the innovative.

The digital platform launched on this occasion supported artists and designers who found their creative resources in heritage and innovatively transposed their findings into the present. This year's concept was placed under the sign of innovation and inspiration in the field of design, my part of the exhibition together with the French designer Philippe Guilet and the Armenian designer, Aram Nikolyan. This came not only as a collaboration between creatives with a diverse cultural background, but also as a confirmation that the foundation of any culture is essential, and could often represent the birth place for many contemporary design-based projects. The project opened its doors on "The International Day of The Traditional Romanian Blouse", 24th June, with an installation that combined the traditions with the technological innovations. The last ones translate into augmented reality applications, film screenings, video mapping and the launch of "Măiastra" digital platform. There were a series of artists that joined this multidisciplinary dialogue, such as the sculptor and illustrator Ana Zoe Pop that recontextualizes into metal sculptures, abstract, sublimated, and high expressiveness forms inspired from ancestral signs. Another artist invited was Maria Cioată, with her fragile and yet strong ceramic pieces, inspired by the "tree of life" symbol and the signs embroidered on the traditional blouses. In the product design area, we introduce the architects Peter Constantinescu and Oana Mureșan (QuestDome) that have designed the exhibition stands for the items I displayed. Alongside, master's students from the University of Arts and Design in Bucharest, Romania, Irina Irimia and Răzvan Mureșan had shown their graduation thesis, focused on augmented reality, a project coordinated by Dr Ioana Sanda Avram and the Pink Strip Productions. (Fig. 5)

Trying to convey the core idea of my professional practice throughout the installation displayed (Fig. 6), I have created items using upcycled traditional fabrics, as well as ancestral crafts, that have been reimagined as contemporary pieces. Our traditional arts and crafts

Figure 5: Image from Galateca gallery archive, exhibition “Măiastra: Virtual fairies” item by Aram Nikolyan. All rights reserved, 2016.

represent our most valuable and authentic feature, a belief that followed throughout my professional path and could be seen translated my work. The ethnographic study of my childhood surroundings became the starting point of my creative path, and it took a permanent leading role when I understood that only through exploring this unique heritage would I be able to pursue making of design that would acclaim the national identity and consequently, my deepest values. I firmly believe one’s distinctiveness is rarely disconnected (on different levels) from the heritage and ancestral values. As Ana Iuga quotes in her paper, entitled “Contemporary traditional clothing in Maramureș”, “The gifts of this argument reveals that clothes do not merely communicate aspects of cultural and social belonging, but they are active agents in creating a person’s identity, in relation to one’s gender and broader sociality”. “If people from one village go and settle elsewhere, either in Romania or abroad, they also recreate their community symbolically by means of material culture” [2].

Philippe Guilet, the French designer joining the 2016 exhibition with a selection of couture items (Figs 7 and 8), shares the same believes and great passion towards craftsmanship, himself being the mind behind “100% RO.PREJUDICES” project. An amazing couture collection produced with the contribution of over 50 Romanian artisans

Figure 6: Image from Galateca gallery archive, all rights reserved, 2016 exhibition "Măiastra: Virtual fairies" items by Andra Clițan.

from different regions in Romania. The collection consists of 34 outfits, reinterpreting the Romanian cultural patrimony such as the wooden roofs in Maramureș, the painted "Easter Egg", the "Endless Column" of Constantin Brâncuși, the traditional crafts in leather, ship skin, pottery, glass, embroidery, metal – using a modern artistic expression. The collection was part of a wider project initiated by the 100% RO NGO, in a move to promote Romania's cultural patrimony and image abroad, defying the negative stereotypes against Romanians at a national and international level.

Figure 7: Image from Galateca gallery archive, all rights reserved, 2016 exhibition "Măiastra: Virtual fairies" items by Philippe Guilet.

Figure 8: Image from Galateca gallery archive, all rights reserved, 2016 exhibition "Măiastra: Virtual fairies" overall image.

Aram Nikolyan, the third designer invited to join the exhibition, is another creative that shares a common interest towards heritage and craftsmanship, being a previous collaborator back in 2010–2011, within the project "Fashion Road: Dialogue across Borders", a 2-year collaborative project aimed at promoting intercultural dialogue and cross-border collaboration through which fashion designers from Armenia and Europe researched the past for ideas and inspiration. It was an EUNIC (European Union National Institutes for Culture) project organized by the British Council, the Czech Centers, Goethe-Institute, the Danish Cultural Institute, and the Romanian Cultural Institute, in partnership with the Armenian Fashion Council. The project received the support of the European Union through the Culture Program (2007–2013). The project brought together young fashion designers from Armenia, the Czech Republic, Denmark, Germany, Romania, and UK which studied the traditional costumes and art of the participating countries and explored the role of the findings in contemporaneity. Each Armenian designer was paired with a European designer that worked together towards designing a four-item capsule collection, myself being elected to team up with Aram, marking our first collaboration. Our works had to reflect the cultural heritage, values, and traditions of the participating countries which we explored during the residencies. Following this collaboration, Aram Nikolyan was invited to present his work in Romania, in a wish to not only enforce the idea of this multidisciplinary program, but also encourage further and deepen the multicultural collaborations between designers and creatives.

4.2 Architecture

The case study presented as a best practice in using sustainable materials and aiming to link the sustainable houses of the future to the arts and crafts of the past is Sustainable EFdeN House [3]. EFdeN is an interdisciplinary team with over 40 members from several universities in Bucharest that over the last two years has designed, raised the necessary funds, and built the EFdeN Signature house prototype. EFdeN was born in 2012 and in 2014 became the First Research Center for Comfort Conditions in Romania. This organization is also a

partner of Galateca Gallery, and together they've collaborated on a series of sustainability art and design events, included "Măiastra" program, 2021 and 2022 editions. We have chosen this example, as the EFdeN House incorporates natural features, local materials and design items created by local craftsman and designers, therefore the impact this project had upon community is important. Their aim was to create an atmosphere which is complementary to the human behaviour and his activities. The focus is on the concept of interconnectivity with nature in a symbolic way and beyond, because human life has always been linked to nature. The house was presented for the first time in "Solar Decathlon", an important competition in the Middle East, and even though the EFdeN team had to face the challenges of the Middle East's climate, which is not always so friendly, they have managed to integrate the European technical standards in the prototype. The green element was their strong point, as it plays multiple roles in the architectural overall concept. It acts both as passive strategy and as an ambient element, and most importantly, a strong reference to the Romanian rural landscape, where life transpires in harmony with all natural elements of the environment.

The large glazing allows the house to establish a visual relationship with the surrounding vegetation, therefore the green element becomes a significant part of the interior's setting. Apart from that, the terrace is a special and intimate space, protected by the outer perforated skin, where the occupants are encouraged to spend their time.

Wood is very well integrated in the house, since not only it is sustainable, but also is one of the most used materials in the traditional Romanian houses, one of the first natural material people learned to use, and it never lost its popularity. These days, it's particularly prized for being a natural and environmentally friendly product. Forestry is a rare example of something that has the potential to be completely sustainable: if you plant a new tree for every old tree, you cut down, you can go on using wood forever without damaging the planet. Growing trees remove carbon dioxide from the atmosphere and planting more of them is one way to reduce the effects of climate change, the material is one of the oldest, but the construction is innovative.

From an urbanistic point of view, the house is designed to create micro-communities and provide all the necessary resources. In Romania it addresses young people, oriented towards nature and sustainability, with an average income. This is an important study case, as it is impacting not only the local community by including local creators and materials in the process, but also has an important education role in creating a link between the modern ways of using sustainable concepts and implement them by taking into consideration traditional local crafts and traditional way of life of coexisting with the natural elements that surround us.

Figure 9: Image from EFdeN archive, all rights reserved, The simulation of the EFdeN Signature house prototype.

4.3 Arts

The 6th edition of "Măiastra" exhibition, held in Galateca art gallery, back in 2018, was shaped around the theme of traditional inspiration and feminine energy, observed from a visual art perspective. A collaborative art installation, was created by three artists from Cluj Napoca, Romania, winners of the "IA-Otherwise/She-Otherwise" open call program, Ioana Olăhuţ, Elena Ilash and Alexandra Mureșan. Having different artistic expressions, we can encounter a series of spectacular metal pieces created by Elena Ilash, paintings using vibrant colours by Ioana Olăhuț and glass sculptures imagined by Alexandra Mureșan, all linked through a connect–renew collaborative vision that inspires creatives to rethink craftsmanship and ancestral heritage. Following this path, the works produced retain the soul of the nation in the form of history, local materials used and cultural identity.

This exhibition is an example for multidisciplinary art installations created by artists united by the same values. The works of art presented explore artistic expressions, such as induced force, undisguised fragility, displayed intransigence, malleability of forms, transparency and opacity, seduction by presence, vivid colours, deformed shapes.

Ioana Olăhuț, the first artist introduced, manifests a special interest for everything that is well thought out, rigorous expressions, as well as a continuous affection towards handmade approaches. Her art oscillates between painting, scenography and installation, causing the intimate coexistence of elements from seemingly diametrically opposed worlds, which creates by association new conceptual, emotional and aesthetic spaces of articulation. Relevant to the contemporary dimension of the concept of metamorphosis, her latest works are visual reflections on the fragile border between natural and artificial, on passing rites, regardless of whether they are of biological, psychological or of social nature, on limited experiences that freezes or accelerates development, revealing a world of existential edges.

Alexandra Mureșan uses glass as a central material for her artistic endeavours, as she believes that "glass stands under the sign of transparency, like democracy and love. She believes that transparency allows sight into an object, but does not guarantee a full discovery. The guarantee of looking outside is looking inside".

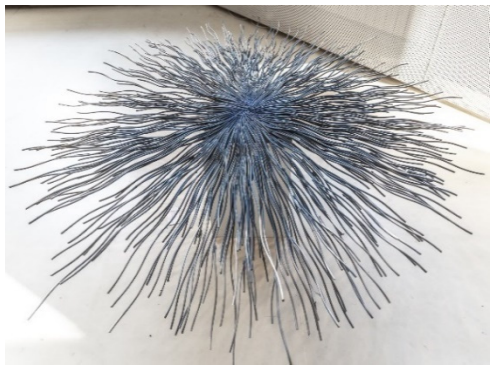

Figure 10: Image from Galateca gallery archive, edition "IA-Otherwise/She-Otherwise", works from Elena Ilash and Ioana Olăhuț. All rights reserved, 2018.

Figure 11: Image from Galateca gallery archive, edition "IA-Otherwise/She-Otherwise", works from Elena Ilash and Ioana Olăhuț. All rights reserved, 2018.

The third and last artist selected for the exhibition is Elena Ilash, who says: "I make objects and forms, in which the tumult of connections, the meetings between planes and matters represents a fusion of formal elements, which are suspended in space in a gravitational descent or in an ascending direction. My transpositions are most often a denial of the full, an absence of an actual body, anatomical details that draw organic shapes in space. There are fragments of ideal creatures, an expression of being, of existing otherwise. It is the need to search for identity, the search for the whole, in fact a personal experiment of approaching the sensory plasticity of space and time".

After introducing the artists involved in the project, it is fair to say that the 2018 "Măiastra" exhibition stands as a good example for a multidisciplinary collaboration, where artists from various parts of the country come together, united by the same inspirational path, themes, uses of materials, as well as methods and practices inspired by ancestral symbols and heritage. Alongside the common approaches, the desire is to make also a statement highlighting the importance of women in local communities, rural and urban, then and now.

The three case studies introduced, while different in creative focus, share the same outcome, that of sustaining cultural heritage spreading beyond the community where it started. It shows that it is possible to use heritage, whether material or immaterial, to sustain a small community, making sure it is protected from an environmental point of view, whilst insuring a positive social and economic impact. All projects discussed have an undeniable contribution to the resurgence of material and immaterial culture, through few points: the designed objects have been produced using locally sourced materials, together with local makers, in order to become the basis for the exhibitions showcased throughout the program. The items displayed utilizes symbols and ancestral elements from different regions in Romania, having therefore a direct impact on spreading awareness on a national and international level. Architecture and arts, as well as design projects have a direct contribution on reimagining the natural living and giving a purpose to all the communities that lost their traditions because of industrialization.

5 CONCLUSIONS

Throughout the mentioned case studies, we show that heritage elements and ancestral practices are adapted and integrated into contemporary design and art projects, that could provide relevant models to be acquired by the younger generation. Local crafts and practices must be integrated within contemporary initiatives, as well as discussed and presented to the world, in order to insure their perpetuation to future generations. This will not only provide awareness towards them, but also exposure, attracting more lucrative opportunities and therefore a sustained development.

By generating and discussing initiatives that lead to sustaining local creatives (artists and designers) as well as makers (craftsmen), we are not only offering support to the ones involved, but we could potentially create new collaboration formulas to be adopted on a national and international level. By introducing interdisciplinary exhibitions and open call project-based interactions, we believe we have succeeded in highlighting the links between these spheres and drawing the public's attention towards the following:

- The impact that multidisciplinary initiatives have upon communities, opening the path for new perspectives.
- The necessity in promoting local crafts, materials, or symbols to better understand and apply them by creatives from different fields.
- The importance of establishing interaction platforms for creatives, within national and international visibility.

- The continuous adoption of authentic and traditional crafts as means for modern inspiration, while sustaining local economies is essential.
- The necessity of integrating ancestral crafts into contemporary designs to ensure continuity of local aesthetics.
- Support local craftsmen for art and cultural projects, in order to keep alive local heritage and promote them to the world.
- Discuss similar case studies within international frameworks to exchange know-how and best practices.

REFERENCES

[1] Taylor, The study of dress history, 2002. https://cms.thehorniman.net/object/ARC/DEZ/691/.
[2] Iuga, A., Contemporary traditional clothing in Maramureș. DOI: 10.7592/FEJF2016.66.iuga.
[3] Appreciations to Claudiu Butacu, Ioana Csatlos, Corina Fugaru, Dalia Stoian. https://efden.org/.

DESIGNING "CLOUDS" FOR A FLEXIBLE USE OF EDUCATIONAL SPACE: RESEARCH AND DIDACTIC EXPERIMENTATION FOR PUBLIC ENGAGEMENT IN THE POST-PANDEMIC ERA

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ABSTRACT
As part of the curriculum of the courses "Materials and Design of Building Elements" and "Urban Planning I", first-year students of the undergraduate programme in Architecture at the Department of Architecture of Pescara, together with undergraduate students from the "Design and Construction" undergraduate laboratory, were involved in an experimental design and construction activity. The project was based on the innovative use of digital design and fabrication techniques and sustainable materials for the design and construction of small buildings, the "Clouds", whose social aims respond to the post-pandemic condition. The laboratory's experimentation and research activity, coordinated by professors Daniela Ladiana and Piero Rovigatti of the Department of Architecture in Pescara, and visiting professor Camilo Cifuentes of La Salle University in Bogotà, Colombia, focused on designing structures to support cultural activities in schools or educational spaces in neighbourhoods characterised by high dropout rates and educational poverty. The small buildings proposed in the final elaborations of the courses respond to the requirements of lightness, ease of construction and reversibility to facilitate self-construction by school communities. The work focused not only the content but also on teaching methods, implemented through a process of comparison and collaboration among students from different courses and levels. A further phase of work, for the construction of models and verification of the technical and economic feasibility of the project, involved local companies.
Keywords: schools, educational poverty, culture-based urban regeneration, low-cost functional upgrading, digital design and fabrication, teaching based on digital and real models.

1 INTRODUCTION

Schools have always represented the space delegated, by statute and institutional mission, with promoting in children the discovery and practice of various forms of cultural expression. This process naturally begins with reading, followed by all that concerns culture in its most open and inclusive expression. According to the Treccani Dictionary, a school is in fact an "institution of a social character which, through organised and structured teaching activity, tends to provide education, human and cultural training, specific preparation in a given discipline, art, technique, profession" [1].

The Latin origin of the Italian word for school – *scuola* – is also interesting: "scuòla" (pop. or poet. *Scòla*) s. F. lat. *Schŏla*, from the Gr. *Σχολή*, which originally meant (as *otium* for the Latins) "free and pleasant use of one's strengths, especially spiritual ones, independent of any need or practical purpose, and later a place where one attended to study".

"Play" is, again according to the definition found in the Treccani Dictionary, "any freely chosen activity to which children or adults devote themselves, individually or in groups, without any other immediate purpose than recreation and leisure, developing and exercising at the same time physical, manual and intellectual abilities" [2].

Observed from this particular point of view, it is difficult, however, to recognise, today, in the albeit exemplary organisation of Italian schools, the presence of spaces and equipment where students can exercise this free and pleasant use of their strengths. If we agree on

assigning play this characteristic, trying to thematise and explore this aspect of school activity becomes particularly interesting, also in light of the difficult and complex experience of teaching during the time of COVID-19 [3].

The "INsegnalibro Clouds" project was promoted within an urban regeneration programme devised by the Pescara Department of Architecture, as part of an extended partnership involving public and private third sector subjects. The project stems from the idea of testing, within the project partner schools, innovative spaces and devices dedicated to fostering and exploring these cultural practices also in a playful and creative sense. The idea was to open them up – from concept to construction – to creative contributions from the final users of these spaces, namely children. *INsegnalibro* was in fact conceived as a cultural-based regeneration project, primarily for children living in socially marginalised neighbourhoods in the suburbs of Pescara.

INsegnalibro is, therefore, a project of investigation, discovery, urban reconnaissance and storytelling. The project was designed to reactivate and establish a network of sites of shared culture for the rebirth of Pescara's Rancitelli, Villa del Fuoco, Fontanelle and San Donato neighbourhoods. The project began in January 2020 and ended in June 2021, with the F. Di Giampaolo library, Neighbourhood House. Starting from the basic hypothesis of the Urban Future Culture Plan, promoted by the Italian Ministry of Culture: "Culture that generates beauty, and regenerates places and social relations", the project attempted to implement it through a varied and complex programme of actions, both tangible and intangible, involving a large number of associations, schools, cultural and academic institutions and ordinary citizens, developing a network that has already been active in the neighbourhoods for some time [4].

INsignalibro project, community narratives

Responsabile scientifico e coordinamento di progetto
Piero Rovigatti, DdA

Operations and support group for activities in schools
Ludovica Simionato, Paola Lavorgna, con Asia Fusco e Mirella Perrone

Schools and related associations
Comprensivo Pescara 1 (Teresa Ascione, Assunta Negro, Maurizio Carafelli, Anna Paola Pizzolante); *Istituto MIBE* (Raffaella Cocco, Donatella Nubile, Daniela Giampaolo); *Istituto Manthonè* (Michela Terrigni, Camillo Giammarco); *PAS* (Dario Tiberio, Giorgia Ranieri, Martina Graziani); *Comitato di Quartiere. Per una nuova Rancitelli* (Francesca di Credico, Daniela Lariccia); *Garage Lab* (Francesco Calandra e Maria Grazia Liguori)

Site web: https://www.bibliotecacasadiquartierepescara.it

Figure 1: The working team and the associations involved in the "INsegnalibro" project.

Figure 2: "Literary Clouds": the location points of the concept, design and building workshops.

2 PUBLIC ENGAGEMENT FOR PRIMARY SCHOOLS

2.1 The "INsegnalibro" clouds project

Schools are among those structures most affected by the COVID-19 restrictions. An analysis of data concerning schools has exposed a concerning amplification of educational poverty and dropout out rates produced by the pandemic. It is now clear that the time spent away from school, from the school community, has carved out a deep and difficult to bridge furrow for this generation of students. This situation imposes the need to identify short-term solutions capable of multiplying the opportunities for meeting, studying, sharing content and discussion, to reverse current phenomena, particularly in economically and socially fragile neighbourhoods.

During the pandemic, research and didactic experimentation at the Department of Architecture of the "Gabriele d'Annunzio" University of Chieti and Pescara looked at the theme of public engagement related to the emerging critical issues faced by the area's schools. The intent was to define possible interventions for the redevelopment of schools and important places for the education community in the Rancitelli, Villa del Fuoco, Fontanelle and San Donato districts.

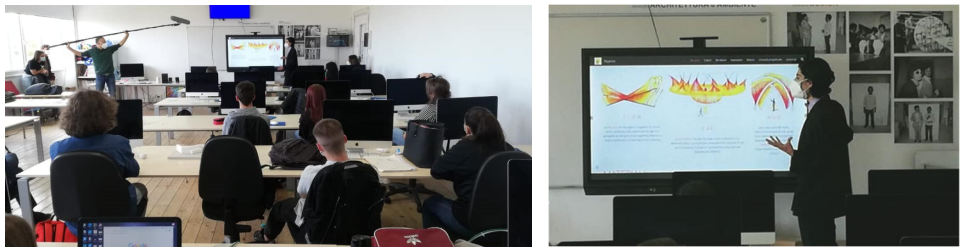


Figure 3: Creation of a "Literary Cloud" by students from the MIBE Art School.

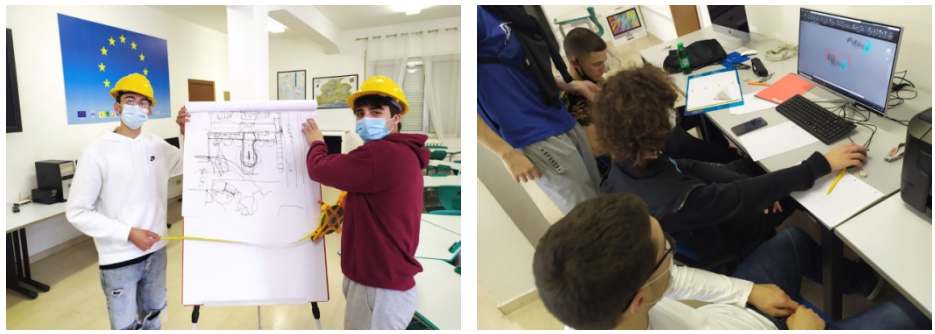


Figure 4: Creation of a "Literary Cloud" by students from the Manthonè Technical Institute.

The didactic experience described here, for the concept and construction of the "Clouds", was developed as part of the activities organised and promoted by the INsegnalibro project, for the networking of places for cultural sharing and the rebirth of neighbourhoods. The project focused on defining immediate, simple and potentially effective actions, primarily for children and adolescents living in these neighbourhoods. The aim was to defend their basic rights, such as access to education and play, services and urban commons, to counter rising educational poverty and support opportunities, well-being and social redemption.

The "Literary Clouds" represented one of the most challenging actions: the first phase involved designing and setting up spaces, together with children and young people from the participating schools, and the production of devices that serve the most basic cultural activities – reading a book, listening to music, attending a small theatre, music or film event – all within existing schools and their often vast and unadorned outdoor spaces, now of particular interest and value in light of the new rules of health distancing imposed by the COVID-19 emergency.

The project began with several workshops on the concept, design and construction sites for various cultural service devices – hosted in the three schools involved in the project: Comprensivo Pescara 1; Istituto Manthonè; Liceo Artistico MIBE. This was followed by the activities carried out within the university courses "Urban Planning 1" (Prof. Piero Rovigatti) and "Materials and Design of Building Elements", taught by professors Daniela Ladiana and Camilo Cifuentes (visiting professor, Universidad de La Salle), as part of the DdA undergraduate course in Architecture at the G. d'Annunzio University of Chieti and Pescara.

Figure 5: An indoor "Literary Cloud" created by children at the Ugo Foscolo School.

Figure 6: An outdoor "Literary Cloud" created by children at the Ugo Foscolo School.

This simultaneous and complementary nature of the activities carried out by different schools represented one of the programme's most important wagers. A wager partly won, thanks to the joint efforts of teachers and directors from different disciplinary and institutional backgrounds. A common trait lay in the initial suggestion, evoked in the project's title, "The Literary Cloud": an isolated and even autonomous space, located either inside or outside the participating schools. The "Cloud" is a place where children can find acceptance and shelter, read a book, watch audio–visual content or listen to music, and much more. It is also an antenna, and an external cell, of the mother Neighbourhood House library, to which the "Clouds" are connected. This connection is both material (the Library supplies the Cloud with books and other cultural content), and immaterial, because through its accessory devices (video, network screens) it acts as a vector for the initiatives – seminars, meetings, activities – that animate cultural life in the neighbourhood of which the Library is the "House". This suggestion took shape in different design solutions, anticipated by studies using models and experiences gathered from the research. During a first phase of the

workshop, high school students were also involved in a search for interesting case studies. Their work produced a participatory map, available at: https://www.google.com/maps/d/u/0/edit?mid=1IiDc5RhjzW01HITNmhEAmJr6PyPVBVyJ&ll=0.8300771966894942%2C0&z=2.

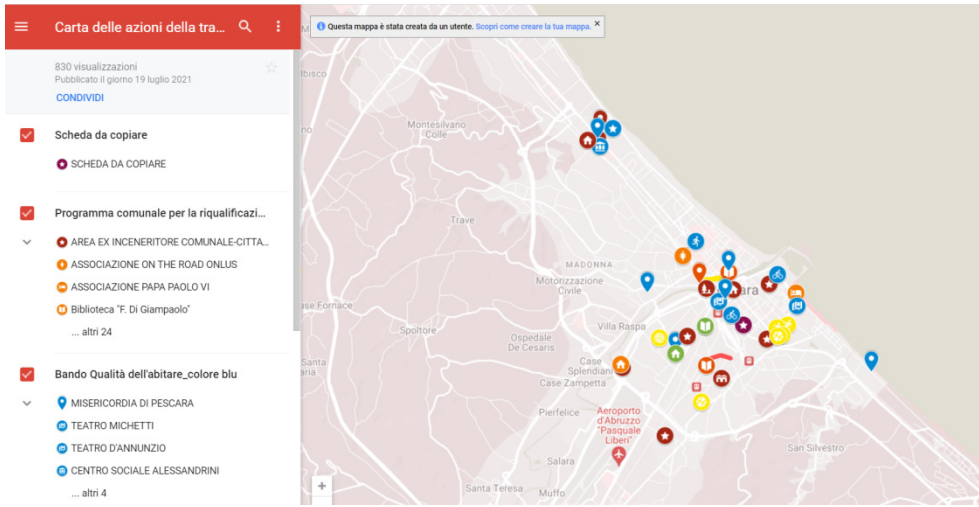


Figure 7: Participatory map of case studies of interest produced by high school students.

The Literary Cloud is, in short, the idea that the teachers, researchers, school administrators, children and young people involved in the project all tried to realise. Their work began with early concept and design workshops, initially remote, though with the hope that the evolution of the COVID-19 emergency would soon allow for a return to classroom activities, and the realisation of interventions whose *raison d'être* is precisely their collective nature, to be carried out in safety, within the education community, to which they are addressed. Some hypotheses remained on paper, at the concept level; others led to the creation of scale models, based on projects accompanied by initial feasibility studies; others finally led to the creation of actual prototypes, such as those created by the team led by the teachers of the "Comprensivo Pescara 1" course, in collaboration with secondary school students. Their work has already been put into use in their schools. The initial programme was further defined in the activities of subsequent projects, including one launched as part of the "This School is a Common Good" project, under the umbrella of the Ministry of Education's Summer 2020 School Plan, at the same school, and with the development of the project described below, developed by a team of 5th grade students directed by Daniela Ladiana and Camilo Cifuentes.

Architecture students were asked to model "small buildings", in the form of a pavilion, which could be used inside a school building to articulate its spaces and enrich its possible functions.

2.2 Didactic experimentation

The didactic experiment involving students in the study of Public Engagement in Pescara's peripheral contexts was conducted as part of the undergraduate Course in Architecture, in the

1st year courses "Materials and Design of Building Elements", "Urban Planning I", and subsequently in the 5th year undergraduate "Design and Construction" laboratory.

Students were asked to develop a concept for the "Literary Clouds", isolated and even autonomous spaces to be placed within existing schools, where children could read a book, listen to music, watch audio–visual content, etc. University students were previously introduced, through a cycle of seminars, to the implications of the relationship between architecture and pedagogy. Subsequent teaching and design experiments were carried out at different levels of complexity, influenced primarily by the use of graphics software. This activity aimed at the creation of 2D and 3D models through an approach and the simultaneous continuous verification and refinement of the buildability of the design concept through the digital production of real models at various stages and scales of this process.

During the first phase of work, the design exercises assigned to students of the "Urban Planning I" and "Materials and Design of Building Elements" courses were coordinated by their respective professors: the choice and analysis of the real contexts in which to insert the "Literary Clouds" were the theme of the "Urban Planning I" course, while the "Materials and Design of Building Elements" course focused on the technological and environmental aspects of the concept.

The most interesting proposals were selected from the work developed by first-year students. This evaluation was benchmarked against the objectives of the Public Engagement initiative. Their work was presented to fifth-year students as a working hypothesis to be critically developed in terms of function and buildability. The designs were studied by different groups based on different interpretations of the proposed theme. This phase of the teaching process involved not only stakeholders who brought their knowledge of the issues and aims at hand, but also companies interested in providing resources and technologies for the solution of socially relevant issues in their own local reality.

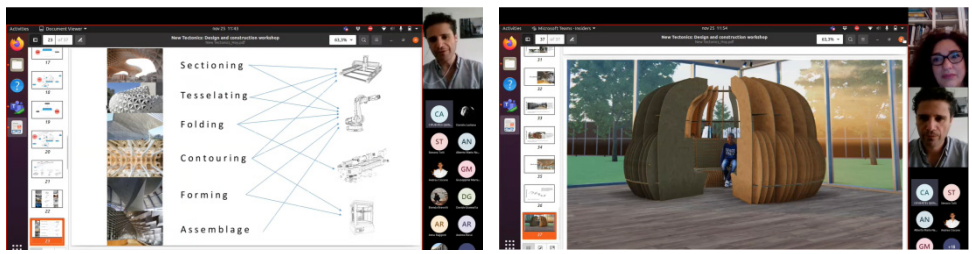


Figure 8: Parametric architecture seminar for the design of the "Literary Cloud" developed by professors Daniela Ladiana and Camilo Cifuentes (visiting) as part of the course in "Materials and Design of Building Elements".

The involvement of these companies proved particularly effective in bringing a concrete dimension not only to the ends pursued, but also to the means of pursuing them, thanks to the detailed description of available resources and processes for the realisation of the different proposals. Discussions with company technicians enriched the teaching by emphasising the importance during the design process of the specific constraints arising from the characteristics of the materials and fabrication processes made available.

The materials and building techniques adopted introduced students to technological innovation characterised by sustainability through the concept of "frugality", which combines environmental with social and economic issues [5].

Figure 9: 1:10 scale models of the “Literary Cloud” produced by students of the first year course “Materials and Design of Building Elements”.

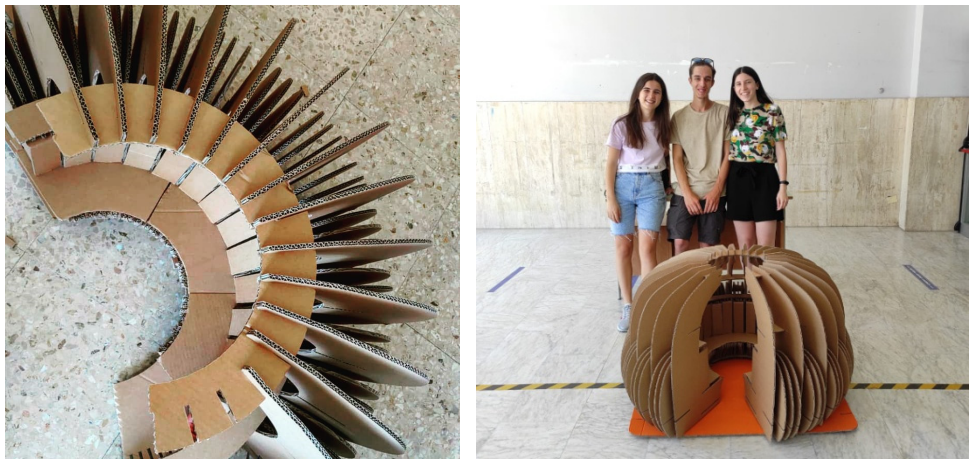
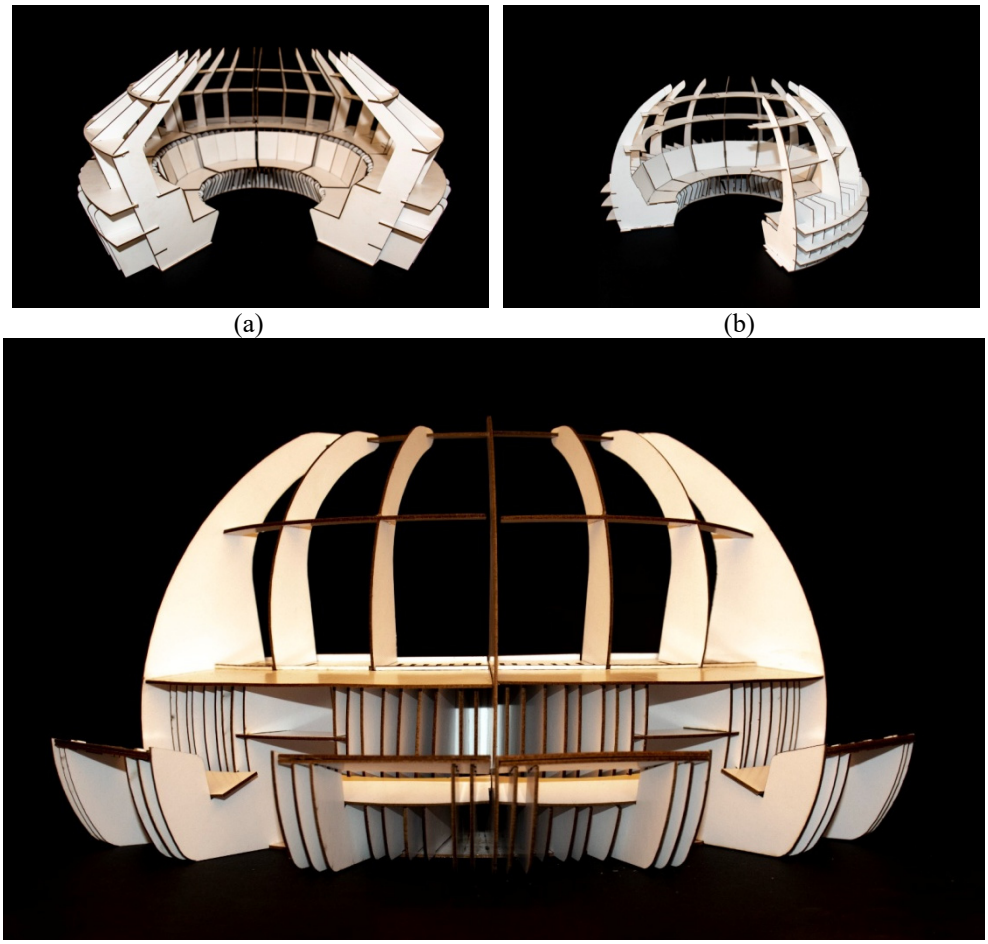


Figure 10: 1:3 scale models of the “Literary Cloud” produced by students of the first year course (Marta Mutignani, Elena Fusco, Alberto Narcisi).

This approach involves working toward technologies capable of effectively responding to the demand for goods and services for those with limited purchasing power, while respecting the environment. Designing for frugal innovation means implementing only the fundamental performance aspects, i.e. only those strictly necessary and important, excluding excessive engineering, to ensure simple modes of use and low maintenance.

Frugal innovation was, in fact, adopted as a possible field of study for the identification of an effective response to the need to provide new spaces to host cultural activities in schools, or in places where educating communities are active, in order to counter the emergency of educational poverty exacerbated in the urban peripheries of Italian cities by the recent pandemic. This was achieved by reducing the economic and environmental costs of products and processes through a reformulation of their complexity.

Pursuing low-cost innovation required students to carefully analyse and define the essential spatial, functional, structural and building aspects of the project. Designing the



(a) (b)

(c)

Figure 11: 1:10 scale models of the "Literary Cloud" produced by the fifth year "Design and Construction" undergraduate laboratory. (a) Students A. Ciccone, A. Gianfelice, F. Manocchio and A. Palermo; (b) Students M. Borghese, B. Bravetti; and (c) Students S. Monar, E. Sabato.

"Clouds" essentially translated into the task of conceiving low-cost, lightweight, easy to assemble and disassemble, recyclable and disposable low impact constructions [6].

The scientific-disciplinary contents of the courses were based on the notion that developing an architectural project is equivalent to establishing technological relationships that constantly recompose the project in relation to paths and information that emerge during the development of the model [7]. In fact, the prototype project is implemented as an active system for integrating and weaving together the various aspects of an architectural programme, the physical qualities and behaviour of materials, and the contextual, physical and social environment.

Figure 12: Rendering of the adopted solution initiated at prototyping with undergraduate students (S. Gatto, D. Giannotta, A. Luce, L. Onorato, F. Remigio, A. Rossi).

Digital design tools were considered fundamental tools for promoting the ability to develop and control language in relation to the complexities of the project. Digital technologies are thus integrated in design as part of a process that regulates the information and interactions among the elements involved in the definition of form and which also configures the relationships between design and construction [8]. The constant involvement in the courses of experts provided by local companies producing the materials used in the experiments proved fundamental: ICO for corrugated cardboard, ICC for honeycomb cardboard, Walter Tosto for the support of nesting and cutting process optimisation for the creation of the 1:1 scale prototype.

From a scientific and pedagogical point of view, the adoption of an "object-based learning process" in the design exercise applied to prototyping was certainly fundamental: an approach centred on the active role of the student who uses physical objects, in our case models, to trigger a deeper and more lasting learning experience [7].

According to this pedagogical model, adopted in the design workshop, the contact between student and model – progressively perfected through the teacher–student and student–class relationship – stimulates interest in deepening the technological, theoretical and instrumental knowledge necessary for the design and realisation of the object of study, enabling it to be applied, with creative ability, in other design situations [9].

The second characteristic aspect of this approach is that the teaching of technological design for prototyping models leads student toward a more "integrated" learning process, so to speak, that "integrates" knowledge of design, geometry, material and structural characteristics. In addition, there are also important aspects of the real context, such as the optimisation of production and the economic feasibility of the model. The third important element is that of bringing students closer to the evolution of supply/demand, towards widespread production practices and open-source design that will increasingly characterise social and economic reality in the near future.

Figure 13: Knowledge as a "common good": Presentation of the work developed by the students of Prof. Rovigatti's Urban Planning course at the library, neighbourhood house, "F. Di Giampaolo".

3 CONCLUSIONS

The realisation of the "Clouds" prototype was based on an experimental teaching methodology that integrated first year courses in different disciplines, with courses from the same disciplinary field but from different years. In the assignment and development of the themes, this approach to teaching saw courses within the framework of the PE activities of the Pescara Department of Architecture working with schools in the periphery, characterised by educational poverty and high dropout rates; finally, the phase of realisation involved local businesses.

Such approaches evidently led to a higher degree of involvement and acquisition of skills by students, thanks to the adoption of a design process characterised by greater, curiosity, resourcefulness and the ability to discuss and verify results. Great importance was focused on the possibilities offered by digital design and production, which allows design hypotheses to be quickly and effectively grafted onto reality. This allows for greater possibilities for self-control and self-correction, and permits direct verification of the buildability of hypotheses formulated. It was, in effect, a matter of supporting a design process in which the student carries out the "trial and error" process more independently, thanks to the facilitation of feedback between reality and digital model.

In this experience we can point to some partial but encouraging observations as initial results: the youngest students showed a greater perception and ability to represent space and equipment in relation to ergonomics and anthropometry; a greater understanding of the problems related to the realisation of joints and connections; a deeper acquisition of the importance of the characteristics of materials. Final year students, on the other hand, demonstrated a greater ability to govern the relationship between material, structure and form; a greater awareness of the relationship between form and the construction process also in its economic implications.

Important results were achieved on the level of relations and implications between the Department and the local context, thanks also to the organisation of communication and

dissemination activities tracking the progress of the work, such as public events and exhibitions in the places affected by the students' projects, used to share content with the communities involved.

Despite what was a demanding and articulated process, positive "clouds" are still on the horizon in the schools and urban commons of the Rancitelli-Villa del Fuoco and San Donato neighbourhoods in Pescara: "Literary Clouds", filled with good drops of a new and fresh rain of words, sounds, colours and images for the thirsty Pescara suburbs, which await new horizons of good sociality, serene community life, outside and beyond an emergency whose end we have all been waiting for.

ACKNOWLEDGEMENTS

We would like to thank all of the companies who donated their time and resources to the development of the prototypes: ICO for the use of corrugated cardboard; ICC for the use of honeycomb cardboard; Walter Tosto for nesting support; Gb Grafica for the optimisation of the 1:1 scale prototype cutting process. Thanks to graduate student Simona Tolli for her collaboration in documenting the prototype realisation process.

REFERENCES

[1] Definition of scuola (school). https://www.treccani.it/vocabolario/scuola/. Accessed on: 23 Jun. 2022 (author's translation).
[2] Definition of gioco (play). https://www.treccani.it/vocabolario/gioco/. Accessed on: 24 Jun. 2022 (author's translation).
[3] Working Group for the Convention on Rights of the Child, I diritti dell'infanzia e dell'adolescenza in Italia. 12° rapporto di aggiornamento sul monitoraggio della convenzione sui diritti dell'infanzia e dell'adolescenza in Italia. https://comune-info.net/scuole-aperte/il-loro-mondo/. Accessed on: 3 Aug. 2022.
[4] Rovigatti, P. & Simionato, L. (eds), Cultura come cura. Esperienze di rigenerazione urbana a base culturale nei quartieri prioritari e complessi, al tempo di Covid 19, Carsa Edizioni, Pescara, pp. 1–236, 2021.
[5] Weyrauch, T. & Herstatt, C., What is frugal innovation? Three defining criteria. *J. Frugal. Innov*., **2**, p. 1, 2017. DOI: 10.1186/s40669-016-0005-y.
[6] Eekhout, M., Verheijen, F. & Visser, R. (eds), *Cardboard in Architecture*, Ios Pr Inc.: Amsterdam, Netherlands, 2008.
[7] Cache, B., *Architecture Words 6: Projectiles*, Architectural Association: London, 2011.
[8] Gane, V., Parametric design: A paradigm shift? Thesis, Department of Architecture, Massachusetts Institute of Technology, 2004.
[9] Georgiev, G.V. & Taura, T., Using idea materialization to enhance design creativity. *Proceedings of the 20th International Conference on Engineering Design (ICED15)*, 27–30 Jul., Milan, Italy, 2015.

SECTION 5
URBAN TRANSPORTATION AND PLANNING

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EXPLORING THE LINK BETWEEN TRAVEL BEHAVIOUR AND SUSTAINABLE MOBILITY

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ABSTRACT
Today's society, which is built and developed based on time and access, seeks to consider these values in different modes of transportation. But what influences these values is the behaviour of users and the pattern they choose. The present study seeks to reveal the factors affecting the behaviour and travel pattern of transportation users and their changes over time by reviewing the relevant literature. Finding and recognizing these changes is critical to finding user behaviour patterns because transportation network performance, policies, planning, and sustainable mobility goals result from these behaviours and changing user patterns over the years and the interactions between them. On the other hand, we know that behavioural patterns are due to users' needs and are different in different population groups. Their preferences and choices will be very different in different situations. Thus, unstable economic, demographic, cultural conditions, existing or lacking infrastructure, mobility habits, technology, and shared mobility can change users' behaviour or lead to an urgent need to change the pattern. This principle can appear in different countries and under different policies and facilities. Therefore, understanding the behaviour of users in sustainable transportation life is extremely important.
Keywords: travel behaviour, urban form, mode choice, sustainable mobility, social-economic factor.

1 INTRODUCTION

We live in a time of change that affects every part of our lives, including our movement patterns. Mobility in today's world is increasingly a guarantee of health and a sign of society's present and future well-being, so despite emerging trends such as self-driving cars, alternative energy sources, and environmentally friendly travel modes (such as cycling and walking), moves towards higher stability. While particular attention is paid to mobility, the search for sustainable transport policies to reduce the adverse environmental effects caused by the increase is also clearly visible. The mobility pattern as an essential part of transportation has a vital role in the efficiency of a city, which in combination with travel behaviour, can provide the conditions and requirements of communication and the surrounding space.

The population in a country shapes their daily activities based on mobility, manifested in travel behaviour according to their particular conditions and needs. Users' behaviour can follow a regular pattern or be irregular due to various factors. It should be noted that with the growth of urban areas, more fundamental challenges arise, which has caused the behaviour cycle of users to undergo many changes, which at first glance is deeply influenced by individual factors and socioeconomic conditions, and urban form. This means that each population segment is considered by factors such as gender, age, education, or income. Each demographic group has its own travel needs and has different time and financial resources available that can change their behaviour. Therefore, it becomes more necessary to find the relationship between these factors and their effect on this cycle.

It is obvious that mobility and gender are influenced by each other. On the other hand, the travel pattern depends on the life cycle to a large extent, which shows the impact of age on the travel behaviour of users [1]. Because the travel needs of young people, middle-aged people, and the elderly change with age, they change and reduce their ability to move and access the transportation system [2]. On the other hand, there is a strong correlation between

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poverty and transportation deprivation, i.e., lack of access to transportation and full social participation [1]. Therefore, along with rapid socio-economic development, the choice of travel mode due to travel behaviour changes drastically, and it is accepted that research on travel behaviour is of great importance.

It is noteworthy that urban form and the built environment influence user behaviour cycle changes. Since cities differ in internal components such as spatial design, socio-economic distribution, spatial structure, and infrastructure, investigating the relationship between the built environment and travel behaviour provides essential knowledge to inform land use and travel-related environmental policies. It also provides for sustainability purposes, doubling this issue's attractiveness. We have seen extensive theoretical and experimental contributions in this field in recent years. How the environment affects travel behaviour and how people's decisions in space and time are compatible with the surrounding environment.

2 METHODOLOGY OF THE LITERATURE REVIEW APPROACH

A systematic literature review was used to complete this article concerning the most cited papers on travel behaviour, followed by a corresponding overview of the obtained results. This selection of bibliographic sources is based on authoritative publications such as Chang et al. [3], Yang et al. [4] and Maciejewska et al. [1]. From the key concepts (travel behaviour, choice of travel mode, sustainable mobility) based on the subject, research was done in Google Scholar, Researcher Gate, Scopus, or Academia.edu to obtain the necessary information. The search was limited to collecting about 102 publications (e.g., articles, books, theses). The selected publications mainly focus on documents published since 2010 (Fig. 1).

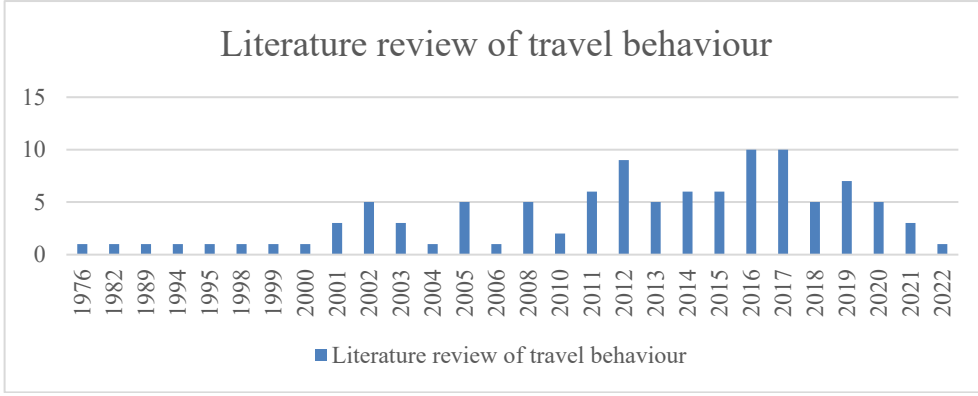

Figure 1: Year of publication of the 106 documents selected in the Literature review of travel behaviour.

Fig. 1 shows the reviewed publications. Publications have been considered based on very important, important and medium importance, and then according to the research topic, the most relevant publications, the most cited and the most important, and also considering the publications of recent years have been selected. This selection also guarantees the diversity of publications for any type of systematic approach, which of course, does not mean that the remaining publications are less important, but in this way, we search for the most relevant and important publications. These publications have been systematized using a Microsoft Excel file.

3 CHARACTERISTICS OF TRAVEL BEHAVIOUR

Societies are increasingly looking for the concept of urban planning on a new level to use it as an effective strategy to reduce car dependence. However, reaching this concept is impossible without understanding users' travel behaviour. Therefore, at the beginning of work, we need to know the main characteristics of users' travel behaviour, which undergoes many changes over time under the influence of various factors. These behavioural characteristics mainly include travel purpose, time, distance, and mode.

3.1 Travel purpose

The purpose of travel usually includes commuting and achieving recreational, shopping, tourist, and social goals. Of course, it has also been stated that journey is primarily influenced by the time dimension commuters use to commute on weekdays, especially during peak hours. However, during off-peak and weekends, passengers tend to change their travel goals to allow them to use shared vehicles such as bicycles.

3.2 Travel time

Travel time is mainly determined by factors such as the purpose of travel and the natural and built environment. In addition, travel times can change underpricing due to policies, transportation benefits, and weather. In his study on shared vehicles, Mateo-Babiano et al. [5] found that using such devices as shared bicycles can reduce the average travel time to less than 30 minutes. But another study states that, despite HOV (high occupancy vehicles) lines' availability, passengers using private cars experience shorter travel times [6]. On the other hand, as mentioned, the weather affects this feature. Seasonality is essential because summer transportation, especially shared vehicles, is more than winter use [7].

3.3 Travel distance

Travel distance is influenced mainly by the purpose and time of travel. In this case, we can refer to a study that was conducted in 2014 and showed that half of the origin–destination pairs were less than 3 km, which was deeply influenced by the purpose of the trip [8]. Another study on the impact of car use shows that the service and non-use of a car in terms of distance to the place of work of schools/universities for drivers in France were similar and did not change much [9].

3.4 Travel mode

A large body of literature shows that the choice of travel mode is one of the first characteristics of travel behaviour that changes due to influencing factors. A study of travel mode choice in the UK confirms that the share of car use declines in older age [10]. It is also acknowledged that traditionally, higher-income passengers travel more by private car. Bhat and Lockwood [11] observed that high-income individuals with driver's licenses drive more. Regarding the level of education, Plaut [12] and van den Berg et al. [13] both showed that highly educated people travel more by public transport (mainly leisure trips). On the other hand, it is said that car ownership also determines car trips. Finally, people living in larger families use fewer non-motor modes than people living in smaller families.

Changes in travel behaviour characteristics, such as reducing the number of trips, changing the purpose of travel, and choosing the mode of travel, can reflect the distribution, spatial organization, and efficiency of jobs and urban housing. In addition, it can overshadow

the decision-making mechanism of people (such as the place of work and residence), so the discovery of the relationship between travel and transportation behaviour and the factors influencing this relationship during periods of mobility research is integral.

4 WHAT FACTORS AFFECT TRAVEL BEHAVIOUR?

With the ever-increasing growth of the population and economy of cities, most municipalities have considered and tried urban transportation to meet people's needs. Meanwhile, urban planners had long thought urban land use might be the only factor affecting transportation travel behaviour. In this regard, the first empirical studies [14] compared transportation fuel consumption at the aggregate level (usually between cities or urban areas). Later, more studies investigated other influencing factors at the individual level. At the beginning of this way, some studies targeted other influencing factors other than the urban structure. Gradually, several empirical studies were conducted to include demographic and socioeconomic variables in the analysis.

4.1 Urban form and built environment

Due to urbanization and civilization, various functional areas are emerging in cities, including residential, commercial, educational, etc. It is noteworthy that the environmental parts of a city are closely related to people's daily travel activities. In terms of density, the distance between the city and the built environment, the urban form can play an essential role in the synergism and environmental and social conflicts of urban sustainability. On the other hand, it is related to mental well-being, which is an integral part of social sustainability. Therefore, the analysis of this factor can be separated into two aspects:

1. built environment,
2. housing and choosing a place to live.

4.1.1 Built environment

It isn't easy to distinguish between urban form, sustainable transport practices, and even travel behaviour because various factors influence this relationship. Factors such as income, family composition, and labour force participation have a unique role in commuting behaviour and choice of transportation method. Secondly, the location (either in the city centre or in the suburbs), the compactness of the residential environment, and the availability of transportation methods cannot be denied. Thirdly, the purpose of the trip is along with the length of the journey and the choice of travel mode. Based on this, the researchers analyzed the impact of the built environment, the impact of city size, density, mixed land use in cities, public transport provision, and the behaviour of the urban system.

But the most extensive and cited study on the effect of density goes back to Dimitriou's study [15] on car energy use in 32 large cities in Europe, the United States, Australia, Asia, and Canada, which shows that petrol consumption decreases with increasing population density. It shows the change in behaviour in this field.

On the other hand, the dispersion of urban land use in a wide area may lead residents to use private cars. So, in general, for the residents of the city centre, the commuting distance increases with the size of the city. On the other hand, for non-business trips, the space may be reduced, and therefore the behaviour changes to more active modes of travel. It should be noted that the density of cities should be high enough to provide an acceptable level of services and jobs to residents.

A study known as Nordic, which examined 30 studies on the impact of urban form on travel behaviour during a period from 1982, can also be considered as one of the complete

researches, although experimental, that has been carried out during the last three decades. There are significant differences between the five Nordic countries regarding research activities in this field [16].

Li and Zhao's research [17] show that the probability of owning a car can have a lower effect on kilometres travelled by work or non-work vehicles in mixed-use areas. This study, conducted in Beijing, showed that people who prefer to live near the subway system and travel on foot are more likely to own a car in the future than others. They also acknowledge that increasing the variety of land use in access to living facilities in neighbourhoods near the station can improve the transportation system's performance by reducing dependence on cars.

Some researchers question the built environment's impact on car ownership and state that this issue and neighbourhood renewal have only a limited role in reducing car use. According to Ewing and Cervero [18], the characteristics of the built environment include residential density, land use composition, urban form, access to destinations, distance to transportation stations, and parking provision, and most of the existing studies on the impact of the built environment on car ownership and its use; it is mainly concentrated at the neighbourhood level. But opponents doubt whether the local built environment can help reduce car ownership and shift behaviour toward other modes. Studies such as Khattak and Rodriguez [19] and Aditjahdra et al. [20] British studies also prove this issue.

Zhang et al. [21] also found a non-linear relationship between accessibility measures and the built environment and car ownership, showing that local accessibility plays a more critical role in predicting car ownership than regional accessibility and transportation. A study examines the development of stationless bike-sharing. Considering that the subway or bus station cannot accurately reflect the origin and destination of people, this solution has been proposed to provide planners with a new opportunity to discover the functions of the urban area. Because sharing helps to solve the problem of first and last mile by creating seamless connections between modes of transportation, so the feature of proximity to destinations in high data coverage makes it an ideal source for understanding land use distribution and understanding travel behaviour; therefore, it enables the discovery of functional urban areas [3].

In East Portland, the research investigated the intelligent mobility space in disadvantaged and low-income areas. The result showed that lower car ownership, income, and license rates lead people to rely heavily on modes other than private cars. But unfortunately, this can also mean they get fewer opportunities in the region because transportation services outside the desired core density are more minor [22]. It is also acknowledged that the development of shared transportation in urban form has dramatically changed individual travel behaviours. In addition, it can also reflect the decision-making mechanism of the place of employment and residence.

In their study on travel satisfaction and the built environment, Mouratidis et al. [23] state that neighbourhood density based on population affects transportation and thus the average walking distance to stops and the number of trips, and considering that parking conditions and the availability of the local store are usually different with the density of the area, however, in most metropolises, the density of the neighbourhoods is influenced by the distance from the city centre. Accordingly, it overshadows the travel behaviour in the direction of choosing the mode. In this regard, many articles, mainly in Europe but also in America, Australia, and Asia, have shown that residents of suburban neighbourhoods travel longer overall distances by car than their inner-city counterparts.

Although many researchers found significant differences in travel choices between people living in urban and suburban areas, the built environment's impact on travel behaviour may

be indirect through travel attitudes and preferences. Studies have shown that people want to find themselves in a neighbourhood that facilitates using their preferred mode of transportation. Wang and Lin [24] analyzed travel behaviour and attitudes before and after residential relocation in Beijing. It finds significant effects in the justifications of travel before and after moving to the environment and admits that travel attitudes have been more preferred in this issue.

Along with these studies, researchers showed that people often change their travel mode after moving independently from the previous and newly built environment.

4.1.2 Choosing a place to live and housing

A significant number of studies showed that people partially choose their living place in specific neighbourhoods to be able to travel in their desired direction. A new residential context has the potential to disrupt previous travel choices and can potentially change travel behaviour. Therefore, residential relocation can be considered an important event in life and can create new contexts in travel and travel restrictions. Even so, travel behaviour, in this case, is also affected by attitudes.

The extent to which a residential location is chosen based on travel preferences may also affect changes in travel behaviour after relocation. Suppose people self-select some neighbourhoods based on their travel experiences. In that case, they will likely use selective travel modes through local areas (e.g., suburban neighbourhood rotation, public transportation, and active suburban travel). Many types of research have focused on the relationship between the built environment and travel behaviour at the local scale. Still, the housing characteristics in all of them have shown the most substantial impact on user behaviour, which offers its position in the urban structure [16], [18], [25].

Is it essential to match the residential neighbourhood based on the attitude toward living in a high-density community. Also, based on travel by alternative means instead of a car [26] travel by public transportation [27] and residential preferences of passengers [28] have been determined that the residential area does not match the attitude of 23.6% to 51.4% of the people. It is mainly explained by the fact that the choice of a residential place is influenced by broad factors such as the distance to the workplace, different preferences in the family, and the limitations of people's budgets that can limit it.

Based on interviews with 15 people who lived in three locations in Oslo (inside the city, suburbs, and along the urban railway, a low-density area with poor access to public transport), Næss [29] found the mobile lifestyle of most people and their behaviour, it specifies and states that proximity to work and leisure activities are less influential in choosing a place to live. There is more flexibility based on the preference for public transportation. Mouratidis et al. [23] state that, given that most daily trips are made outside the residential area, the total trip distance is likely to be more influenced by the distance from the residence to the end of the journey than reflecting the characteristics within the residential area and it usually reflects the central structure of the city.

4.2 Social factors and demographic

Social conditions are different in each part of the population and are defined by various factors. This section is described under the demographic information that reflects the lifestyle and behaviour of users regarding the choice and time of daily travel; of course, the research of socio-economic differences in indicators such as budget or travel time, or even travel goals will be shown different behavioural patterns.

4.2.1 Gender factor

Mobility has not been equal for all socio-economic groups. On the other hand, Daily mobility and gender are inseparable and mutually influence each other. Cities are not gender-neutral and offer significant opportunities to reduce gender gaps and inequalities [30].

A priority issue is incorporating a gender perspective in urban planning and mobility studies. The travel habits of gender groups have long been recognized in the literature as an outcome and a cause. Given that the current transportation system is still male-centric, women are more deprived of vehicle access. Lack of gender equality in access, opportunities in the labour market, and full participation in the activities offered by the city deprive women.

According to Brown [31], women do multipurpose activities and plan several things in one trip. Similarly, Iveth et al. [32] argue that gender differences in mobility are due to physical and social factors rooted in the region's specific cultural characteristics. Because the possibility of access to a car is limited for women under certain conditions and relying on public transportation in a car-oriented world, they may emphasize their time budget. Furthermore, women often do not share car-centric transportation preferences.

Therefore, the discussion of gender mobility can be divided into two categories. The first category has two dominant themes [1]: social justice and environmental perspectives. This part of the research shows that using women's experience is helpful for future sustainable transport development. As Matthies et al. [33] and Polk [34] point out that women are more stable in travel behaviour and show a greater tendency to reduce car use.

Another central aspect of this discussion is related to the difference in access and use of existing modes of transportation.

Seeking to understand the gender gap, studies generally refer to the different social roles that men and women play in the home, workplace, community, and family. Traditionally, women make more daily trips and organize multiple activities due to organizational time frames. Many of these behaviours are part of caring mobility, that is, accompanying children and the elderly. Therefore, as shown in Motte-Baumvol et al.'s study [35], this has led to more trips and women's reliance on slower modes of transportation such as public and pedestrian transportation.

On the other hand, it has been shown that gendered travel preferences go beyond social structures, resources, and transportation opportunities. Maciejewska et al. [1] study examined the changes in travel behaviour between 2007 and 2012; they say that the female travel pattern has been less flexible, and only minor changes have been made. They also state that the results showed a significant reduction in the use of private transport in men, who may have been forced to do so by financial circumstances. This study also showed that when men's travel habits are affected by an external factor, they tend to change it by reducing their dependence on the car and choosing alternative methods.

4.2.2 Age

Although it has been proven that gender is one of the main factors in changing the pattern of mobility and behaviour, alone and without considering age, it is not enough to understand travel behaviour. Age also has a noticeable effect on daily mobility. Living longer and maintaining an active lifestyle creates opportunities and aspirations for various activities. However, functional limitations become more familiar with age, and many older people acquire more than one disability that can complicate travel. Boschmann and Brady [36] found that as the passengers get older, they make fewer and shorter trips, although women make fewer and shorter trips than men.

The routine activities of young people differ from those of middle-aged or older people depending on their age, time, and budget they have to invest in transportation. A clear and

relevant example is the demand schedule for night-time transportation, which mostly begins in late adolescence and young adulthood.

The travel needs of middle-aged people are usually focused on accompanying children and paying attention to parents. Because older people have limited mobility and rely more on the public, and as people age, their ability to move and access decreases [2]. It is also important to note that since women are usually the ones who are involved in caregiving tasks, the gender gap in travel due to age will usually increase during the middle period because that is when women's lifestyles will differ the most from their male counterparts.

It has also been stated that middle-aged men usually do not balance their travel goals and focus more on leisure activities. On the other hand, older adults use more active means of transportation, mainly walking, and women are more involved in this field than men.

4.2.3 Education and household size

The level of education and size of the household has a positive and significant relationship with users' travel behaviour. Travellers with a bachelor's degree or higher are less likely to choose driving in their travel chain but have a more positive association with public transportation. Users with high education, especially the elderly between 35 and 54 years old, prefer to limit their activities after work. They are considering the importance of travel time.

Married people find it easier to own a vehicle because they accept more responsibilities at home and organize more trips. Especially in the case of families with children under the age of six who tend to adjust the order of their activities in a way that leads to the choice of a model with a shorter travel time and distance. But low-income travellers mainly use public transportation and non-motorized modes due to economic constraints.

4.2.4 Social inequality

Mobility policies and the resulting travel restrictions can cause and intensify social inequalities. Some groups of people suffer from injustice due to personal and spatial heterogeneity. Vulnerable groups will probably face more deprivation than others, potentially leading to adverse effects on their physical and mental health due to their choice of travel due to physical and economic conditions. As Yang et al. [4] show in their study in China affected by the effects of the COVID-19 pandemic, its results are visible in cities with large populations. They have created a significant discussion about social inequalities and deprivation caused by transportation-related factors.

4.3 Economic factor

Since the economic conditions also determine mobility, the resulting fluctuations can strongly affect the user's travel behaviour. On the other hand, mobility also determines the amount of money and temporary resources people have available. It is worth pondering that financial crises affect men more than women. Therefore, the traces of factors affecting travel behaviour show their combined existence.

A case study in Greece suggests that the tendency to reduce the number of personal trips leads to reduce costs [37]. This shows that despite the crisis, people satisfy their needs and desires with travel and therefore seek to increase their activities.

Disruptive events such as the financial crisis caused significant changes in living conditions that go beyond reducing economic activity. The impact of economic problems in the literature is considered an essential and mutually reinforcing finding between poverty and transportation deprivation. Meanwhile, it can be expected that the number of trips will decrease with the increase in unemployment. Marquet and Miralles-Guasch [38] have found

that unemployed people tend to substitute their daily commute for other purposes. Similarly, considering the close relationship between income and car use, Maciejewska et al. [1] state that the crisis can lead to the substitution of the car for other modes of transportation, as well as changes in distances travelled and places of activity.

One of the financial crises affecting mobility behaviour was the Great Recession that started in 2008 and spread rapidly in the international financial circuits, especially in Southern European economies such as Spain, Greece, and Italy [39]. It made an impact that caused changes in the mobility pattern, primarily women as captive modal users.

4.4 Psychological factors

There are two approaches in the travel behaviour literature: the theory of utility maximization and the theory of psychological behaviour. The idea of utility maximization assumes that decisions and changes in travel behaviour are entirely rational. Therefore, travellers choose the mode that has the most utility among the alternatives, as determined by their socio-economic characteristics and the service characteristics of the methods. The psychological theory of behaviour assumes that state selection and behaviour change may be considered a general process resulting from behavioural habits. There is a philosophy in this case as a guide that the combination of psychological factors leads to a more realistic representation of the user's behavioural process and thus its better explanatory power.

Studies show that the choice of travel mode is explained by psychological factors both as a rational action and as normal behaviour. Studies also state that psychological factors as logical determinants significantly impact travel intention, and travel behaviour can improve the mode choice model compared to the traditional model. Also, perceived behavioural control greatly affected behavioural sense towards train use in Phnom Penh city and intention to use the motorcycle in Taipei and Kaohsiung in Taiwan [40]. On the other hand, Nordfjærn et al. [41] and Chen and Chao [42] showed that a subjective norm was the most effective predictor of destination and change from private vehicle to public transportation.

Along with this logical procedure, habitual behaviour is also the main predictor explaining travel behaviour. Because habits are also practical in that they are done to achieve a specific goal, studies show that habits influence destination and mode choice behaviour. For example, the habits identified in choosing to travel by private vehicle affect the choice and changes in the travel pattern of private vehicle users. Similarly, Domarchi et al. [43] found that car use habits strongly affected Chilean workers' choice of car use.

In another study conducted in two major cities of Taiwan to investigate travel mode selection behaviours in this area dependent on motorcycles, psychological factors showed a more substantial impact on changing travel behaviour than socio-economic factors. However, according to the reviewed literature, it is not yet clear which is the most vital factor between rational and habitual behaviour.

4.5 Safety

Travel literature usually distinguishes between traffic volume, modal split and traffic distribution over time. On the other hand, any decision resulting from travel behaviour is summarized to reach the intended goals. These decisions lead to risk exposure when combined with traffic, and the safety literature on risk exposure relates directly to travel behaviour. It should be noted that single-vehicle accidents may affect only one vehicle and one road user, while collisions involve multiple vehicles and road users. Risks of accidents and injury resulting from infrastructure, road users and the vehicle used will lead to a link in

the framework of risk and exposure, which includes factors that determine vulnerability to risk. In addition, most perceived risk plays a role in choosing the mode, that is, the idea that the unsafeness of a specific type of vehicle can be an obstacle to its use.

5 CONCLUSION

The advantage of looking at changes in travel behaviour over time is that it is possible to discover general trends. In addition, the background conditions change over the years, so citizens are trying to find strategies and adapt to the new requirements, which is often clearly visible in their behaviour. On the other hand, policies can strengthen the effects of factors affecting travel behaviour. Because there is a belief that the correct design, the application of rational policies and appropriate to the conditions can create suitable environments and encourage people towards active transportation and reduce the use of private vehicles. In the same way, although people present different perception and behavioural patterns methods, the reality of action in the environment with social and cultural characteristics in other comparisons of the country, city, region and neighbourhood creates frequent perceptions and behavioural patterns.

REFERENCES

[1] Maciejewska, M., Marquet, O. & Miralles-Guasch, C., Changes in gendered mobility patterns in the context of the Great Recession (2007–2012). *Journal of Transport Geography*, **79**, 2019.

[2] Steiniger, S., Fuentes, C., Villegas, R., Ardiles, R., Rojas, C.A. & Poorazizi, E., *AccesoBarrio-Medición de la accesibilidad urbana usando perfiles demográficos y OpenStreetMap*, Plataforma Municipal CEDEUS, Municipal Indicator Dashboard View project Acceso Barrio View project, 2017. https://www.researchgate.net/publication/320138411.

[3] Chang, X., Wu, J., He, Z., Li, D., Sun, H. & Wang, W., Understanding user's travel behavior and city region functions from station-free shared bike usage data. *Transportation Research Part F: Traffic Psychology and Behaviour*, **72**, pp. 81–95, 2020.

[4] Yang, Y., Cao, M., Cheng, L., Zhai, K., Zhao, X. & de Vos, J., Exploring the relationship between the COVID-19 pandemic and changes in travel behaviour: A qualitative study. *Transportation Research Interdisciplinary Perspectives*, **11**, 2021.

[5] Mateo-Babiano, I., Bean, R., Corcoran, J. & Pojani, D., How does our natural and built environment affect the use of bicycle sharing? *Transportation Research Part A: Policy and Practice*, **94**, pp. 295–307, 2016.

[6] Xiao, L.L., Liu, T.L. & Huang, H.J., On the morning commute problem with carpooling behavior under parking space constraint. *Transportation Research Part B: Methodological*, **91**, pp. 383–407, 2016.

[7] Zhou, X., Understanding spatiotemporal patterns of biking behavior by analyzing massive bike sharing data in Chicago. *PLoS ONE*, **10**(10), 2015.

[8] Faghih-Imani, A., Anowar, S., Miller, E.J. & Eluru, N., Hail a cab or ride a bike? A travel time comparison of taxi and bicycle-sharing systems in New York City. *Transportation Research Part A: Policy and Practice*, **101**, pp. 11–21, 2017.

[9] Delhomme, P. & Gheorghiu, A., Comparing French carpoolers and non-carpoolers: Which factors contribute the most to carpooling? *Transportation Research Part D: Transport and Environment*, **42**, pp. 1–15, 2016.

[10] Li, H., Raeside, R., Chen, T. & McQuaid, R.W., Population ageing, gender and the transportation system. *Research in Transportation Economics*, **34**(1), pp. 39–47, 2012.

[11] Bhat, R.C. & Lockwood, A., On distinguishing between physically active and physically passive episodes and between travel and activity episodes: An analysis of weekend recreational participation in the San Francisco Bay area. *Transportation Research Part A: Policy and Practice*, **38**(8), pp. 573–592, 2004.
[12] Plaut, P.O., Non-motorized commuting in the US. *Transportation Research Part D: Transport and Environment*, **10**(5), pp. 347–356, 2005.
[13] van den Berg, P., Arentze, T. & Timmermans, H., Estimating social travel demand of senior citizens in the Netherlands. *Journal of Transport Geography*, **19**(2), pp. 323–331, 2011. DOI: 10.1016/j.jtrangeo.2010.03.018.
[14] Keyes, D.L., Energy and land use: An instrument of US conservation policy? *Energy Policy*, **4**(3), pp. 225–236, 1976.
[15] Dimitriou, H., Cities and automobile dependence: An international sourcebook: Peter Newman and Jeffry Kenworthy Gower: Aldershot, UK, 388 pp., *Utilities Policy*, **1**(4), pp. 352–354, 1991.
[16] Næss, P., Urban form and travel behavior: Experience from a Nordic context. *Journal of Transport and Land Use*, **5**(2), pp. 21–45, 2012.
[17] Li, S. & Zhao, P., Exploring car ownership and car use in neighborhoods near metro stations in Beijing: Does the neighborhood built environment matter? *Transportation Research Part D: Transport and Environment*, **56**, pp. 1–17, 2017.
[18] Ewing, R. & Cervero, R., Travel and the built environment. *Journal of the American Planning Association*, **76**(3), pp. 265–294, 2010.
[19] Khattak, A.J. & Rodriguez, D., Travel behavior in neo-traditional neighborhood developments: A case study in USA. *Transportation Research Part A: Policy and Practice*, **39**(6), pp. 481–500, 2005.
[20] Aditjandra, P.T., Cao, X. & Mulley, C., Understanding neighbourhood design impact on travel behaviour: An application of structural equations model to a British metropolitan data. *Transportation Research Part A: Policy and Practice*, **46**(1), pp. 22–32, 2012.
[21] Zhang, W., Zhao, Y., Cao, X., Lu, D. & Chai, Y., Nonlinear effect of accessibility on car ownership in Beijing: Pedestrian-scale neighborhood planning. *Transportation Research Part D: Transport and Environment*, **86**, 2020.
[22] Golub, A., Satterfield, V., Serritella, M., Singh, J. & Phillips, S., Assessing the barriers to equity in smart mobility systems: A case study of Portland, Oregon. *Case Studies on Transport Policy*, **7**(4), pp. 689–697, 2019.
[23] Mouratidis, K., Ettema, D. & Næss, P., Urban form, travel behavior, and travel satisfaction. *Transportation Research Part A: Policy and Practice*, **129**, pp. 306–320, 2019.
[24] Wang, D. & Lin, T., Built environment, travel behavior, and residential self-selection: A study based on panel data from Beijing, China. *Transportation (Amst)*, **46**(1), pp. 51–74, 2019.
[25] Næss, P., Strand, A., Wolday, F. & Stefansdottir, H., Residential location, commuting and non-work travel in two urban areas of different size and with different center structures. *Progress in Planning*, **128**, pp. 1–36, 2019.
[26] de Vos, J., Derudder, B., van Acker, V. & Witlox, F., Reducing car use: Changing attitudes or relocating? The influence of residential dissonance on travel behavior. *Journal of Transport Geography*, **22**, pp. 1–9, 2012.
[27] Kamruzzaman, M., Baker, D., Washington, S. & Turrell, G., Residential dissonance and mode choice. *Journal of Transport Geography*, **33**, pp. 12–28, 2013.

[28] de Vos, J., Mokhtarian, P.L., Schwanen, T., van Acker, V. & Witlox, F., Travel mode choice and travel satisfaction: bridging the gap between decision utility and experienced utility. *Transportation (Amst)*, **43**(5), pp. 771–796, 2016.
[29] Næss , P., Urban structures and travel behaviour: Experiences from empirical research in Norway and Denmark. *Land Use and Travel Behaviour*, pp. 1–24, 2000. http://www.ejtir.tbm.tudelft.nl/issues/2003_02/pdf/2003_02_03.pdf.
[30] Gauvin, L. et al. Gender gaps in urban mobility. *Humanities and Social Sciences Communications*, **7**(1), 2020.
[31] Brown, D., Urban informality and building a more inclusive and resilient green economy: The peri-urban interface: Development, governance and poverty. Urban Africa Risk Knowledge (Urban ARK) View project. http://pubs.iied.org/10722IIED.
[32] Iveth, R.D.L.R., Eric, G. & José Sergio, P.J., Relationships between urban form and mobility: gender and mode of transport. Universidad Politecnica de Cartagena, 2022.
[33] Matthies, E., Kuhn, S. & Klöckner, C.A., Travel mode choice of women: The result of limitation, ecological norm, or weak habit? *Environment and Behavior*, **34**(2), pp. 163–177, 2002.
[34] Polk, M., Are women potentially more accommodating than men to a sustainable transportation system in Sweden? www.elsevier.com/locate/trd.
[35] Motte-Baumvol, B., Bonin, O. & Belton-Chevallier, L., Who escort children: Mum or dad? Exploring gender differences in escorting mobility among Parisian dual-earner couples. *Transportation (Amst)*, **44**(1), pp. 139–157, 2017.
[36] Boschmann, E.E. & Brady, S.A., Travel behaviors, sustainable mobility, and transit-oriented developments: A travel counts analysis of older adults in the Denver, Colorado metropolitan area. *Journal of Transport Geography*, **33**, pp. 1–11, 2013.
[37] Papagiannakis, A., Baraklianos, I. & Spyridonidou, A., Urban travel behaviour and household income in times of economic crisis: Challenges and perspectives for sustainable mobility. *Transport Policy*, **65**, pp. 51–60, 2018.
[38] Marquet, O. & Miralles-Guasch, C., The walkable city and the importance of the proximity environments for Barcelona's everyday mobility. *Cities*, **42**(PB), pp. 258–266, 2015.
[39] Hadjimichalis, C., Uneven geographical development and socio-spatial justice and solidarity: European regions after the 2009 financial crisis. *European Urban and Regional Studies*, **18**(3), pp. 254–274, 2011.
[40] Chen, C.F. & Lai, W.T., The effects of rational and habitual factors on mode choice behaviors in a motorcycle-dependent region: Evidence from Taiwan. *Transport Policy*, **18**(5), pp. 711–718, 2011.
[41] Nordfjærn, T., Şimşekoɨlu, Ö. & Rundmo, T., The role of deliberate planning, car habit and resistance to change in public transportation mode use. *Transportation Research Part F: Traffic Psychology and Behaviour*, **27**(PA), pp. 90–98, 2014.
[42] Chen, C.F. & Chao, W.H., Habitual or reasoned? Using the theory of planned behavior, technology acceptance model, and habit to examine switching intentions toward public transit. *Transportation Research Part F: Traffic Psychology and Behaviour*, **14**(2), pp. 128–137, 2011. DOI: 10.1016/j.trf.2010.11.006.
[43] Domarchi, C., Tudela, A. & González, A., Effect of attitudes, habit and affective appraisal on mode choice: An application to university workers. *Transportation (Amst)*, **35**(5), pp. 585–599, 2008.

TOWARDS SUSTAINABLE URBAN TRANSPORTATION PLANNING IN DEVELOPING COUNTRIES: "DRT" MOBILE APPS AS A CATALYST FOR BIG DATA-BASED DECISION SUPPORT SYSTEM

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ABSTRACT

The term big data refers to huge data sets which have high velocity, high volume and high variety. Using decision support system (DSS), big data can manage transportation demands, budgets, goals, and regulations. Moreover, it can manage different stakeholders and minority groups' needs and requirements, while adapting to environmental, economical and current social concerns. Transportation planning and decision-making faces rapid urbanization challenges in both developed and developing countries since urban planning process and decision makers depend essentially on data collection and analysis. This paper aims to discuss technological mutual line of big data, public transportation types, and DSS through transit mobile apps. The present paper discusses an assumption of reasons to explain why transit apps existed in both the developed and developing countries. It focuses on the developing countries, with a study on six demand responsive transit apps (DRT) used in Egypt to address the existing transit concerns. As a result, a comparison is drawn to comment on these apps' features and big data usage in enhancing transportation decision making in Egypt. Finally, the paper provides comments on still existing concerns and proposes recommendations for a new app development based on the previous apps, to sprint big data-based DSS.

Keywords: big data, urban planning, transportation planning, DRT, mobile apps, decision making, Paratransit, informal transportation.

1 INTRODUCTION

Big data (BD) is a broad range of observational or "naturally-occurring" data produced by transactional, operational, planning, and social activities that are not made for research by default. In general, the term BD refers to huge data sets which have high velocity, high volume and high variety, as well as a complicated structure that makes management, analysis, storage, and processing challenging. An emerging trend in information systems is the extraction of insights and hidden correlations from BD to improve citizen services and help decision-making. However, extracting valuable insights from developing smart cities necessitates generating datasets from various city domains to be integrated and analyzed. Common names for this procedure include BD analytics and BD value chain. Due to the complex, intricate, and multi-criteria character of urban concerns, decision-making in urban planning has generally become more and more challenging [1].

Urban growth in today's world is clearly hampered by poor decisions and citizens' discontent with the current developments. The citizens' contentment represents one of the prerequisite principles of sustainable development, which is still a big problem.

The problem of transportation has turned out to be is a worldwide concern. Nowadays, transit apps are used in both developed and developing countries with different reasons of establishing these apps. The present paper claims the relation between these apps and the country development level. Concerning developing countries, such as Egypt, transit concerns have a significant tangible impact on citizens' life. The present paper aims to draw a comparison between six different demand responsive transit apps (DRT) used in Egypt:

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Waslni app, Careem, Uber, Didi, inDriver, Dinamo apps, Swvl app, and Mwasalat Misr app. This leads the way to understanding and investigating how these apps fulfilled the market and solved the prevailing problems. Finally, the paper attempts to address the existing transit concerns and propose recommendations for a new app combing different stakeholders and sharing the solid background of previous app experiences.

2 DEFINITIONS

2.1 Big data

Kaisler mentioned "The collection of large and complicated datasets that are difficult to process using database management tools or typical data processing programs, including issues such as data capture, storage, search, sharing, transfer, analysis, and visualization" [2]. In 2012, Madden stated that "big data is data that is too large, too quick, or too difficult to process using current techniques" [3]. BD typologies can take many known basics forms that can blend with each other. BD characteristics are developing through time from just three Vs to eight, 12, 14Vs and one C in 2017. BDT sources are increasing each day in certain paths and classifications with different fields' usage; especially the field of urban planning [4]. This data ranges from user logging files on social networks, search engines, and email clients to machine-generated data such as real-time monitoring of sensor networks for dams or bridges (IOT), and various vehicles such as airplanes, cars, or ships. Furthermore, the sources of BD include traditional databases, sensors, log files, GPS systems, text and image files, audio and video files, and streaming data systems [5].

2.2 Smart cities

The term smart city has gained attraction in academia, business and government to describe cities that are increasingly composed of and monitored by pervasive and ubiquitous computing where economy and governance are driven by innovation, creativity and entrepreneurship enacted by smart people [6]. "A city that have digitally embedded devices everywhere built into the very fabric of urban environments", which are used to monitor, manage, and regulate city flows and processes, often in real-time. Many urban residents use mobile computing (such as smart phones) to interact with and navigate in the city, which generates data about its users [7]. "Smart city is found to refer more broadly to the growth of a knowledge economy within a city-region". From this perspective, a smart city is one whose economy and governance is being driven by innovation, creativity and entrepreneurship, enacted by smart people [2].

2.3 Decision making and decision support system (DSS)

The process of choosing a course of action involves identifying an option, acquiring data, and weighing potential courses of action. Using a step-by-step decision-making procedure, decisions can be made. By organizing pertinent information and defining options, this can assist in helping people make more careful, informed decisions. DSS is a computerized information system that uses BD analysis to support decision-making inside an organization or corporation. It gathers data that can be utilized to address issues and improve decisions. A DSS benefit is to increase the speed and efficiency of decision-making, improve the skills of employees to use a DSS, automate complicated managerial processes, free up the time of decision-makers, and improve interpersonal communication within an organization [8]–[10]. There are three main fundamental architectural components which are as follows: The user

interface, database management system (DBMS), model-based management system (MBMS) as shown in Fig. 1.

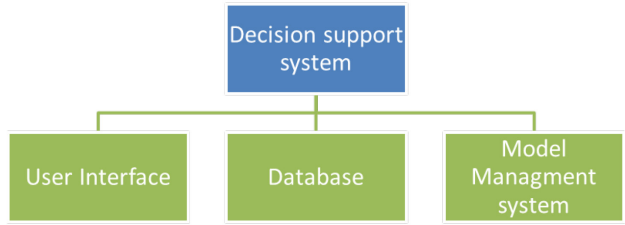

Figure 1: Data process in smart cities and its features.

3 METHODOLOGY AND HYPOTHESIS

The paper seeks to open a discussion in enhancing the decision-making qualities in transportation and urban planning by:

- Reviewing the modern approaches of incorporating BD through smart phones transit apps.
- Highlighting and promoting the importance of the relationship between recording human behaviour and efficient city planning as a catalyst for sustainability.
- Stating and comparing the different working apps in Egypt as an innovative solution made in the developing countries to address the lack of suitable formal transit.

The paper claims that public transit (PT) apps, in the developed countries, are well known and established as a reference to the relatively stable public transportation systems and authorities. As shown in Fig. 2, the sequence of developing needs of transit apps in the developed countries has started as a result of the need to digitize the system to coping with new technologies and serve citizens. These apps generated an important amount of data that would be considered as valuable data, especially in transportation and urban planning development recently. Data is then recognized, analyzed, and visualized to make a certain decision. At that time, developing PT apps is required for a more luxurious and healthier life. In addition, a human self-esteem is needed as Maslow's Hierarchy of Needs.

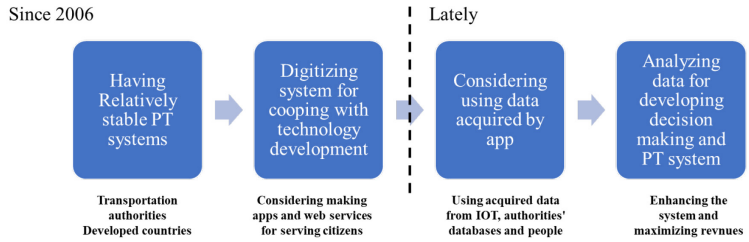

Figure 2: The process of creating transit app in developed countries.

On the other hand, developing countries experience a lake of structured computerized data. However, more and more citizens use technology everyday with their smartphones.

Smartphones are a good and cheap way of collecting data for decision making. Fig. 3 indicates the paper hypothesis about the need of developing countries to develop transit mobile apps. However, it belongs to safety needs and not to the self-esteem level. The needs in developing countries in the recent years belong to a lower level of Maslow's Hierarchy of Needs and not as the beginning of these apps in the developed countries in 2006.

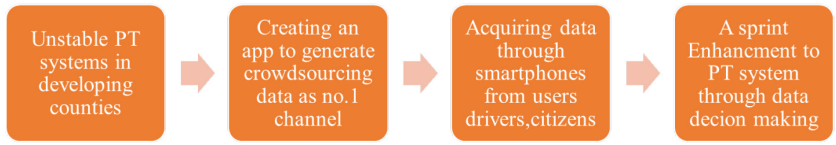

Figure 3: The process of creating transit app in developing countries.

4 LITERATURE REVIEW

The literature review is presented in three parts. The first part shows formal PT (transit) and informal PT (paratransit and DRT) as shown in Fig. 4. The second part reviews the different transit app types. The third part is a comparative analysis between different DRT apps worldwide.

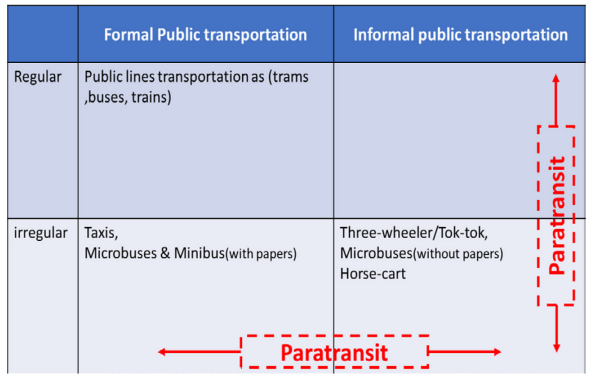

Figure 4: Formal, informal, paratransit in reference to transit types. Informal PT has no legal documents, while a paratransit is an informal PT with legal papers, irregular lines and timetable.

4.1 Formal PT (transit) and informal PT (paratransit and DRT)

The scale of metropolitan centres in developing nations has increased dramatically during the last forty years. In dense centres, low-income neighbourhoods, and congested streets, effective public transportation services are essential. These led to two main types of transit: formal and informal PT.

4.1.1 Formal PT (transit)

Formal public transportation can be defined as vehicle types supported or operated by governmental authorities as trains, buses, ferries, trams, and taxis. "Africa faces crucial challenges as it aims to generate an efficient inter-modal public transport sector that seeks to

enhance the lives of its citizens. Public transport is a challenge for the majority of users, but more so for the poor. More than 60% of households spend on average 20% of their income monthly on transport. It can be as high as 31% in rural areas". High operating and societal expenses, as well as inefficiencies in the various public transportation modes, are some of the difficulties the formal transportation sector is facing. Additionally, the layout of residential areas in pre-democracy times had a significant impact on the commute distance from homes to businesses (many people live far from their workplaces) [11].

4.1.2 Informal PT (paratransit and DRT)

Technically, informal PT services are those operating without official endorsement. This typically indicates that the vehicles and their owners lack the necessary licenses or registration documents from the government to offer the general public collective-ride services. A single person typically owns and operates small-sized vehicles that make up the informal transportation sector. The majority of drivers are young, low-skilled males who moved to the city from the countryside [12].

According to International Association of Public Transport (UITP), informal transport emerges in a context where:

- There is no service for some population because governments, civil servants and the upper classes do not notice this lack of supply, even if it is critical to the economy.
- There is a lack of investment in public services and utilities.
- The public realm and infrastructures are very much car oriented.
- There is fast urban sprawl and city development.
- There is a supply of vehicles that can be shared to transport people.
- Public transport is considered as a private business.
- Public transport is not centred on urban dwellers needs or on any public policy.
- There is potential provided by IT tools [13].

However, this is not always the case in all developing countries. In Egypt, informal PT operates inside cities main roads with official papers registered by government authority. While in Egyptian slums, low-density and dispersed settled areas, legal papers are absent. More than half of all public transportation trips in developing nations are provided by informal, often minor, companies. Based on market shares of travel between large-vehicle PT and small-vehicle paratransit, Godard stated in 2006 that 52% of transportation in Egypt is a paratransit model. In 2021, UITP stated that in many African cities up to 90% of the transport supply is informal [12], [14], [15].

4.1.3 Paratransit as a part of informal PT

In addition to the variability of prices, these services are either door-to-door or flexible enough to deviate from conventional routes. They contribute to optimizing traffic density by decreasing the use of private vehicles, meeting the demands and needs of passengers stemming from such traffic and transport problems. Operators of paratransit are remunerative because they can quickly adapt to shifting markets, are more aware of the needs of their customers, and have relatively minimal operating expenses. By organizing route associations and cooperatives, the present paper shows that they can lower per-seat costs to compete with larger companies. Other advantages of small vehicles are: more frequent headways, sense of passenger safety (due to the closer proximity of riders to drivers), better riding experience such as guaranteed seat, in addition to fleet-footedness as the ability to manoeuvre in crowded city streets compared to lumbering buses [16]. The different types of paratransit are shown in Table 1.

Table 1: Classes of paratransit vehicles and services that operate informally [17].

Class	Service features		Passenger		
	Routes	Schedules	Capacity	Service niche	Service coverage
Minibus/jitney	Fixed	Semi-fixed	12–24	Mixed	Subregion
Microbus/pick-up	Fixed	Semi-fixed	4–11	Distribution	Subregion
Three-wheeler/ motorcycle	Variable	Variable	1–4	Feeder	Neighbourhood
Pedicab/horse-cart	Variable	Variable	1–6	Feeder	Neighbourhood

4.1.4 Demand responsive transportation

It can be defined as a flexible service that provides shared transport to users who specify their desired location and time of pick-up and drop-off. This can be done by using different telematics tools. DRT is not a modern invention because the first formally recorded experiment was carried out in 1916 in Atlantic City. such as phone booking or smartphones. **DRT benefits** can make up for fixed public transport route services and improve mobility in low-density areas and at low-demand times of the day. While many DRT services are implemented primarily to improve social inclusivity and access to services, DRT can also contribute to de-carbonization by replacing private car journeys and facilitating multi-modal travel (for example, linking users to a train station or fixed route bus service). It is necessary to integrate DRT services into the local transport network to be effective. To reduce the carbon dioxide (CO_2) emissions for the passenger per kilometre from a DRT service, operators can optimize routes using the latest technology, select vehicles with lower or zero tailpipe emissions and increase passenger occupancy levels [18].

4.1.5 DRT as a paratransit mode

Traditional paratransit models provide fixed routes and frequency-based services to meet dynamic demands. DRT paratransit system, on the other hand, offers passengers flexibility in parameters like vehicle, route, schedule, and payment methods. It enables the passengers to prefer public transportation to private vehicles and other alternatives [12].

4.2 Types of public transportation apps

There are three major public transport app types in service. These three types include transport provider's apps, general-purpose transit apps, and hop-on hop-off tours apps.

4.2.1 Transport provider apps

These apps are developed for particular transport agencies. These apps only deliver information related to a specific company and have limited operating routes. They offer essential features to users according to a particular company's transportation such as: seat reservation and online ticket booking system for a particular ride in addition to route and schedule information for trip planning. These types of apps are used in bus companies like FlixBus in Europe, or GoBus and Bluebus in Egypt. Paratransit as microbus is operated within the intercity and regional routes as SWVL in Egypt and India [19], [20].

4.2.2 General-purpose transit apps

They come in the category of urban navigation applications. They have collaborations with various transport agencies and deliver information related to routes, ticket cost, time duration, live updates, and ticket booking system. These types of apps serve on a wide scale and operate

in more than a hundred cities or countries. These kinds of apps are on the top as far as the PT apps are concerned. For example, Moovit, Transit, and Citymapper are among the most popular apps of this type. They serve more than 250 million people in over 3,000 cities located in many countries [19].

4.2.3 Hop-on hop-off tour apps

These apps have a straightforward operating model. They are developed to ease sightseeing bus tours within a city or a country. Each tour is designed with multiple stops that are usually famous landmarks where one route covers one or several places of interest or tourist places. With the use of tour applications like Tuk-Tuk Hop and City Sightseeing Amsterdam, people may learn more about routes, stops, static schedules, the current location of vehicles, an offline city map, audio guides, and brief descriptions of well-known landmarks [19], [20].

4.3 DRT apps in developing countries, Egypt

In developing countries such as Egypt, governmental transportation systems suffer from overloading, crowding, and lake of system development as in infrastructure, assets and equipment, data analysis and decision making. Egypt is the Arab's largest market in ride hailing which led to informal transportation, paratransit, and DRT apps. Besides, individuals, start-ups and private entities started to address the problem, trying to solve, and even establish a business model from the solution to get good revenues. Among these initiatives are Waslni app, Careem/Uber/Didi/inDriver/Dinamo apps, Swvl app, and Mwasalat Misr app.

4.3.1 Waslni App

Waslni app was launched in 2017 from abstract developers. It acquired more than 100,000 users since its launch. Waslni was from the preliminary and primitive ideas to help in adjusting formal and informal public transport flow in Cairo and Giza provenance. As shown in Fig. 5 which represents the app UI, the app depended on a database pre-loaded with a description of all possible routes for each prime location loaded in the app.

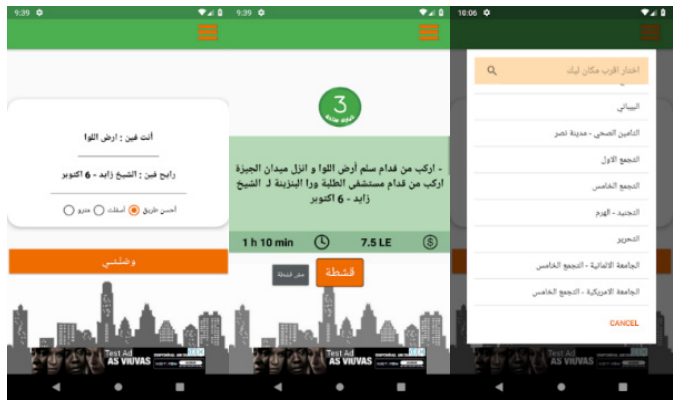

Figure 5: Waslni app UI [21].

The app business model was very simple depending on ads appearing by Google to users. The app has a score of 4.2 on Google Play store. Most of the comments affiliated with early

years are positive. Meanwhile, in the recent time comments are negative, due to new technologies introduced in the market without any update from the developer [21].

4.3.2 Uber, Careem, Didi, inDriver, Dinamo as DRT private cars hailing apps in Egypt

Undoubtedly, **Uber** has changed the way that Egyptians move. International Uber app introduced the car hailing to Egyptian citizens in Cairo since 2014. Uber operates now in five Egyptian cities. According to Hassanein, Uber claims to have 90,000 active drivers throughout Egypt, despite having previously claimed to have as many as 200,000 drivers there [22]–[24].

Careem is a Dubai-based super app with operations in over 100 cities, covering 12 countries across the Middle East, Africa, and South Asia. It works in 14 Egyptian cities. In January 2020, Uber Technologies Inc. spent $3.1 billion to acquire Middle East Careem, buying dominance in a competitive region ahead of a hotly anticipated initial public offering.

Didi is a Chinese ride sharing app, owned to Didi Chuxing Technology Company. It has been launched in the Egyptian market in 2021. The company started its operations in Alexandria (the second city in Egypt), as it is more limited compared to Cairo as the capital. Despite being founded in 2012, the business was able to purchase Uber in China in 2016. Didi is trying to acquire more users by offering free rides and cheap packages [25], [26].

inDriver is a global app with more than 100 million users in 45 countries. It is the second largest ridesharing and taxi app downloadable worldwide in 2020. inDriver model introduced a big different P2P business model than normal car hailing apps, as to request a ride; the user specifies the starting point and destination address of the ride. However, if the passengers have any suggestions for the driver about the price, they are willing to pay, the passenger's pricing offer may be countered by the driver. In many regions of the world, there is a high demand for a model like this [27]–[29].

Dinamo is a local car hailing company that works in specific Egyptian cities as Banha and Asuit. The Dinamo app which was previously named "waslni-banha" was launched in 2017 and was owned by Waslni Company. Dinamo acquired from 10,000 to 50,000 users in their first-and second-generation app. It is considered a very limited app. However, it has a progress in business rather than app or technological development as it is the only app operating in this geo-locations [30].

4.3.3 Swvl app the first DRT paratransit app

Swvl is a revolutionary tech-enabled mobility platform with a base in Dubai that supports mass transit in some of the most difficult and complicated emerging economies in the world. Intercity, B2B, and B2G transportation are all provided by Swvl. Swvl concentrates on mass transit, as opposed to ride-hailing services that concentrate on one-time and private rides. This lowers the price of a ride that might otherwise be unaffordable and lowers emissions. The company uses a unique algorithm to determine the quickest routes, including options for travelling to work or school [31], [32].

4.3.4 Mwasalat Misr app

Mwasalat Misr is a main investment from Emirates National Group. It is backed by the National Bank of Egypt. The company was firstly launched in 2014 and became a member of the UITP in 2016. The transport provider app launched in 2021 serves 32 million customers each year in 74 bus routes with 333 bus features such as accessibility, friendliness, and AC. The app has more than 100,000 users and features: easily track bus routes and stops, adding favourite locations and track buses' arrival time, access Mwasalat Misr routes and fares, planning trips from anywhere and to anywhere, notifications of the latest updates and

promotions; help and support around the clock. As shown in Fig. 6, the app is limited to the company buses only, as it is addressing a certain customer economical category [33].

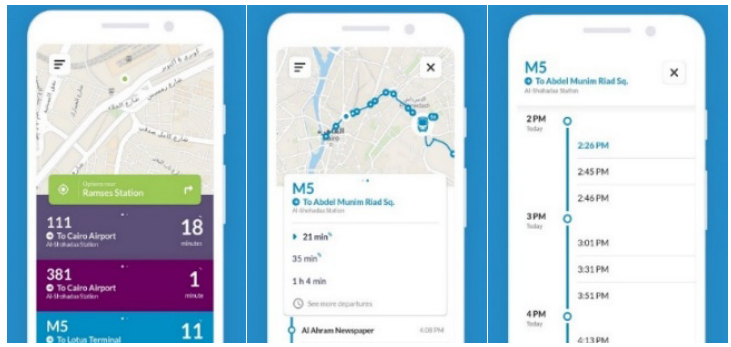

Figure 6: Mwasalat Misr app [33].

5 RESULTS

After discussing different apps in Egypt as a case for developing countries, the different apps were positioned in relation to formal, informal, and paratransit as shown in Fig. 7. All working apps are considered by default a demand responsive transportation (DRT). However, they all have a significant problem in considering the app as formal or informal. On one hand, the apps use licensed vehicles with legal papers. On the other hand, these vehicles are licensed as private, not legally considered for mass transportation, and do not pay taxes as conventional taxis or micro-buses. In addition, these companies operate as offshore companies in Egypt, which means that they do not pay taxes as local operating transit companies.

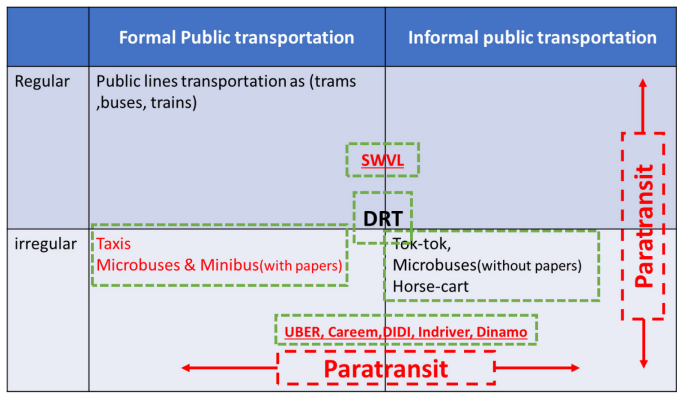

Figure 7: Positioning DRT apps in relation to formal, informal, and paratransit.

In May 2018, the government of Egypt approved a law governing ride hailing services. The country has two major ride-hailing apps, i.e., Uber and Careem. Both apps faced several legal disputes due to policies designed for conventional taxis. Thus, they are expected to create significant challenges for market growth [34].

Focusing on the Swvl app, it was initially developed for reducing chaotic traffic jams. However, the model evolved from organizing the existing paratransit micro-buses, to obtaining new vehicles which are owned by individuals, small bus traveling companies or even owned by the company. This led to a new category of paratransit vehicles which are more expensive than local existing micro-buses and cheaper than taxis and car sharing companies. This model addressed smartly wide customer categories in developing countries such as Egypt, especially from the youth and middle classes [35]. As shown in Table 2, mostly all apps in Egypt focus on one type, leaving the big market open in the other two types. Although Egypt is concerned with monuments and tourism, there is no app that provides this type of service. As a general-purpose app for formal and informal PT, yet no app meets this crucial demand.

Table 2: Comparative analysis between app types.

	Waslni app	Uber	Careem	Dinamo	Didi	inDriver	Swvl	Mwasalat Masr
Transport provider apps		✓	✓	✓	✓	✓	✓	✓
General purpose app								Somehow
Hop-on hop-off tour app								

A comparison is drawn between the different features of DRT apps, as shown in Table 3, to deduce different discussion points. Concerning apps different business models, mobility as a service (MaaS) and transport as a service (TaaS) apps have more features than normal DRT apps. In addition, the technology applied for newer apps offers more essential and friendly features compared to old existing ones. This shows that the very highly competitive market is generating more competitive features. However, disabled people are still not fully supported from all companies. Mwasalat Masr and Swvl are the best bidders in this

Table 3: Comparative analysis between features.

	Waslni app	Uber	Careem	Dinamo	Didi	inDriver	Swvl	Mwasalat Masr
Informative app	✓	✓	✓	✓	✓	✓	✓	✓
A to B route planning		✓	✓	✓	✓	✓	✓	✓
Real time departure and arrivals		✓	✓	✓	✓	✓	✓	✓
Alerts and safety					✓			
Notification		✓	✓	✓	✓	✓	✓	✓
Step by Step guide							✓	✓
Favourites							✓	✓
Trip cost estimation		✓	✓	✓	✓	✓	✓	✓
Ticket buying options							✓	✓
Nearest transport station information							✓	✓
Feature for disabled people			✓					✓
Offering and controlling prices						✓		
Multi modal app								
Using BD as a decision-making base		✓	✓		✓	✓	✓	

comparison. Yet, all apps do not seek to have a multi-modal app even those using with Maas and TaaS. Nonetheless, decision making upon BD for urban planning is not fully understandable by all national apps' decision makers as few research published in transit app impacts in Egypt. Thus, apps using BD are always updating their systems, UI/UX, developing more transit routes, and gaining more revenues.

6 CONCLUSION AND RECOMMENDATION

This paper discusses the concepts of BD, smart cities, and DSS. It highlights the types of public transportation as formal, informal, paratransit, and DRT. Furthermore, the paper claims the reasons of creating transit app in both the developed and developing countries. It scopes transit (DRT) mobile apps working in developing countries such as Egypt. Finally, the paper compares these apps in relation to transit app types, offers solutions, features, and BD usage for the decision making process.

The demand for ride-hailing services is expected to increase significantly in the coming years due to Egypt's increasing urbanization and continuously low automobile ownership rates. The pace of urban expansion in the nation is over 2%, according to Urbanet. This demonstrates that the cities of Egypt must make room for over a million new residents each year. The need for commute services in these recently growing cities has been driven by this.

New ride-sharing businesses in the country are concentrating on innovative techniques including long-distance services, cheaper average prices, and improved safety. Furthermore, newer modes of transportation have been developed as a result of rising fuel prices, the popularity of ride-sharing services, and greater environmental awareness. In order to reduce the ongoing traffic issues in Egypt's major cities, an increasing number of ride-hailing service providers are now offering their services to two-wheeler vehicles. These cars have more appeal in the online ride-hailing market thanks to their reduced prices. For instance, Careem offers metered scooter rides starting from USD 0.38 (6 EGP). The cheapest ride costs USD 0.50 (8 EGP), which is approximately 50% lower than regular car rides [34].

Yet, a one view solution is not the best-case scenario. Studying the Egyptian case, an incremental rational solution must be taken into consideration. A process of starting a national transport app in developing countries is essential to be shared between the government and the private sector. This app should start incrementally and decentralized from the capital, as more problems and complexes will appear in case of addressing the capital at first. This app should contain each legal public transportation and paratransit in one application to work as a multi-modal TaaS app. In addition, it should work as a middle mediator, launching with pre-acquired society knowledge of Swvl and Uber which can be a good start. This insures acceptance from various stakeholders as individuals, transportation authorities, policy makers and government.

This app can aid in facilitating a number of concerns such as:

- **Adopting citizens to chaotic PT schedules:** this could be achieved by real-time data getting from vehicles. Then, data can be accumulated and analyzed to be a real-time prediction tool for jams and conjunctions delay.
- **Wagons real-time crowdedness:** possible features and updates can state vehicle crowdedness, as data coming from smartphones and IOT devices can be analyzed.
- **Micro (citizen) decision making** from the previous features, any citizen can have the power to decide which transit type is acceptable. Citizens can make a decision upon crowdedness, times of arrival and departure, available alternatives and cost.
- **Enhancing dealing with traffic jams** can be achieved by analyzing the missing data of citizens take ins and outs.

- **Real-time info for governmental decision makers:** a control room can be fed with incoming analyzed data from servers to enhance instant decisions based on data.

REFERENCES

[1] Khediri, A., Laouar, M.R. & Eom, S.B., Improving intelligent decision making in urban planning: Using machine learning algorithms. *Int. J. Bus. Anal*., **8**(3), pp. 40–58, 2021, DOI: 10.4018/IJBAN.2021070104.

[2] Kaisler, S., Armour, F., Espinosa, J.A. & Money, W., Big data: Issues and challenges moving forward. *Proceedings of the Annual Hawaii International Conference on System Sciences*, pp. 995–1004, 2013. DOI: 10.1109/HICSS.2013.645.

[3] Madden, S., From databases to big data. *IEEE Internet Comput*., **16**(3), pp. 4–6, 2012. DOI: 10.1109/MIC.2012.50.

[4] Arockia Panimalar, S.V.S.S. & Kathrine, A.V., The 17 V's of big data. *Int. Res. J. Eng. Technol*., **4**(9), pp. 329–333, 2017.

[5] Adam, K., Hammad, I., Adam, M., Fakharaldien, I. & Majid, M.A., Big data analysis and storage. *Proc. 2015 Int. Conf. Oper. Excell. Serv. Eng*., September 2015, pp. 648–659, 2015.

[6] Kitchin, R., The real-time city? Big data and smart urbanism. *GeoJournal*, **79**(1), pp. 1–14, 2014. DOI: 10.1007/s10708-013-9516-8.

[7] Kourtit, K., Nijkamp, P. & Arribas, D., Smart cities in perspective: A comparative European study by means of self-organizing maps. *Innovation: The European Journal of Social Science Research*, **25**(2), pp. 229–246, 2012. DOI: 10.1080/13511610.2012.660330.

[8] Tawde, S., What is DSS? Components and various types of DSS. https://www.educba.com/what-is-dss/. Accessed on 27 Jun. 2022.

[9] Esam, A., What are decision support systems and how they work. CustomerThink, 2021. https://customerthink.com/what-are-decision-support-systems-and-how-they-work/. Accessed on 27 Jun. 2022.

[10] CFI Team, Decision support system (DSS): Overview, components, types. https://corporatefinanceinstitute.com/resources/knowledge/other/decision-support-system-dss/. Accessed on 27 Jun. 2022.

[11] UN Habitat, Public transport system, 2020.

[12] Cervero, R. & Golub, A., Informal transport: A global perspective. *Transp. Policy*, **14**(6), pp. 445–457, 2007. DOI: 10.1016/J.TRANPOL.2007.04.011.

[13] International Association of Public Transport (UITP), Key insights into transforming the informal transport sector. *Knowl. Br*., pp. 1–10, 2021.

[14] Godard, X., Coping with Paratransit in developing cities: A scheme of complementarity with institutional transport. *Futur. Urban Transp*., **2**, p. 5, 2006.

[15] Information and Telecommunications Technology Committee (ITT) Committee, The Internet of Things in public transport, Brussels, 2022.

[16] Coutinho, F.M., van Oort, N., Christoforou, Z., Alonso-González, M.J., Cats, O. & Hoogendoorn, S., Impacts of replacing a fixed public transport line by a demand responsive transport system: Case study of a rural area in Amsterdam. *Res. Transp. Econ*., **83**, 100910, 2020. DOI: 10.1016/J.RETREC.2020.100910.

[17] Cervero, R. & Kockelman, K., Travel demand and the 3Ds: Density, diversity, and design. *Transp. Res. Part D Transp. Environ*., **2**(3), pp. 199–219, 1997. DOI: 10.1016/S1361-9209(97)00009-6.

[18] Alonso-González, M.J., Liu, T., Cats, O., Van Oort, N. & Hoogendoorn, S., The potential of demand-responsive transport as a complement to public transport: An assessment framework and an empirical evaluation. *Transp. Res. Rec*., **2672**(8), pp. 879–889, 2018. DOI: 10.1177/0361198118790842.
[19] Matellio, A guide to develop a real-time public transport app. https://www.matellio.com/blog/a-guide-to-develop-a-real-time-public-transport-app/. Accessed on: 12 Aug. 2022.
[20] Altexsoft, Best public transportation apps: Bus, rail and public transit planning. https://www.altexsoft.com/blog/engineering/public-transportation-apps-apis-and-platforms-maps-scheduling-trip-planning-and-mobile-ticketing/#:~:text= Transportation providers' apps.,widget to use this feature. Accessed on: 18 Aug. 2022.
[21] Google Play, وصلني: Apps on Google Play. https://play.google.com/store/apps/details?id=com.semicolon.wassalni. Accessed on: 18 Aug. 2022.
[22] Uber, How Uber works in Egypt. https://www.uber.com/en-EG/blog/how-uber-works-in-egypt/. Accessed on: 19 Aug. 2022.
[23] Espanol, M., Uber faces new competition in Egypt. https://www.al-monitor.com/originals/2022/03/uber-faces-new-competition-egypt. Accessed on: 19 Aug. 2022.
[24] Hassanein, D., Ride-hailing in Egypt: A global tug-of-war. *Wamda News*, 24 Aug., 2021.
[25] El Masry El Youm, DiDi ride app starts transportation services in Alexandria. *Egypt Independent*, 14 Oct., 2021.
[26] Alaa El-Din, M., Chinese ride sharing app Didi Chuxing to operate in Egypt mid-September. *Daily News Egypt*, 10 Oct., 2020.
[27] Butcher, M., Straight outta Siberia: inDriver raises $5M for its flat-rate ride-hailing app. TechCrunch. https://techcrunch.com/2017/09/07/straight-outta-siberia-indriver-raises-5m-for-its-flat-rate-ride-hailing-app/. Accessed on: 19 Aug. 2022.
[28] Matta, S., The emergence of inDriver in Egypt: A new challenge for Uber's customers' loyalty. C-Tower Chatters. https://www.ctownchatter.com/2021/06/17/the-emergence-of-indriver-in-egypt-a-new-challenge-for-ubers-customers-loyalty-1-1-1-1-1/. Accessed on: 19 Aug. 2022.
[29] Njanja, A. & Kene-Okafor, T., Didi expands, inDriver monetizes to rival Uber, Bolt in Africa. TechCrunch. https://techcrunch.com/2021/10/28/didi-expands-indriver-monetizes-to-rival-uber-bolt-in-africa/. Accessed on: 19 Aug. 2022.
[30] Google Play, 자가격리자 안전보호: Apps on Google Play. https://play.google.com/store/apps/details?id=com.jarirbookstore.JBMarketingApp&hl=en&gl=US%0Ahttps://play.google.com/store/apps/details?id=kr.go.safekorea.sqsm&showAllReviews=true. Accessed on: 19 Aug. 2022.
[31] Hamdy, H., El Deen, B.H., El-Toukhy, I.M., Elsagheer, A. & Mohamed, A., Online bus services: A view of Swvl company. *Handbook of Research on Decision Sciences and Applications in the Transportation Sector*, pp. 178–188. DOI: 10.4018/978-1-7998-8040-0.CH008.
[32] Swvl, Investors. https://investors.swvl.com/. Accessed on: 19 Aug. 2022.
[33] Mwasalat Misr, About. https://mwasalatmisr.com/about/. Accessed on: 19 Aug. 2022.
[34] Grand View Research, Egypt ride hailing service market size report, 2021–2028. 2019.
[35] Stevens, P., Swvl: A green-focused mass transit company, is going public via an all-female SPAC. *CNBC*, 28 Jul., 2021. https://www.cnbc.com/2021/07/28/swvl-a-green-focused-mass-transit-company-is-going-public-via-an-all-female-spac.html. Accessed on: 19 Aug. 2022.

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BEYOND GROWTH: A STUDY ON THE TRANSFORMATION OF URBAN RENEWAL GOVERNANCE IN THE SOUTHERN PART OF THE OLD CITY OF NANJING, CHINA, BASED ON THE URBAN REGIME THEORY

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ABSTRACT

With the transition of China's urbanization to a medium speed, urban renewal has gradually become a new hot spot in China's urban movement recently. It brings new motivation to study China's governance model and urban renewal transformation. The "urban regime" theory has been widely used in studying urban governance because of its solid explanatory function. However, in the past, "growthism" made urban regimes have inevitable convergence, and the research of single time nodes and projects cannot explain the transformation characteristics of the recent urban renewal governance mode in China. Therefore, based on the long-term tracking of the renewal practice in the Southern Part of the Old City of Nanjing (SPOCN), this paper profoundly analyzes the urban renewal governance model of the SPOCN in different periods using the "urban regime" theory and attempts to refine the transformation characteristics of the new urban regime in recent renewal movement. The study found that the practice in SPOCN experienced three different stages of "rapid growth", "opposition to growth", and "exceeding growth", corresponding to the "developmental regime", "progressive regime", and "expanded regime". In the new period of renewal practice in SPOCN, the rise of residents' consciousness and intellectuals has led to the expansion of social power, the transformation of government power, and the withdrawal of market power, forming an "expanded" governance system for the organic renewal. Also, historical culture and people-oriented values have become the core value orientation that dominates renewal movements, and residents' proposals have become the dominant factor affecting the renewal paradigm and policy innovation. However, the current "expanded" regime in SPOCN focuses too much on the will and welfare guarantee of disadvantaged groups, which puts forward new practice and research needs for a sustainable financial guarantee and policy innovation system in this regime.

Keywords: urban micro renewal, urban regime theory, urban renewal, governance, transformation, China.

1 INTRODUCTION

Affected by the turbulent external environment caused by the global financial crisis in 2008, economic globalization has entered a period of "de-globalization", and China's economic development has also entered a new normal of medium and low-speed growth. Over the past decade or so, with the advent of a new stage of sustainable development of human society, such as "carbon reduction", China has actively guided the transformation of its social and economic development model through policies. It successively puts forward the overall development strategies for the new era, such as "Scientific Outlook on Development", "Ecological Civilization", "Two Mountains Theory" [1], "A Community with a Shared Future for Mankind", and "High-quality Development". Among them, space is an essential practical carrier for realizing transformation and development, and the innovation of space production mode is an important starting point for promoting social and economic development power transformation. Therefore, since the 18th National Congress of the Communist Party of China, China has ushered in a brand-new strategic positioning of its

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operation mode on three spatial scales: regional, urban and rural. The "regional coordinated development" was proposed at the regional scale, and the "rural revitalization" strategy was proposed at the rural scale, while the latest "14th Five-Year Plan" proposed a new strategy of implementing "Urban Renewal Action" at the urban scale [2]. This is the first time since the founding of the People's Republic of China and the reform and opening up that the concept of urban regeneration has been placed in the discourse system of national governance that represents China's highest authority, facing a new development transformation from growth-oriented to improvement-oriented.

A large number of studies in the past believe that the main reason why China's social economy has become the world's second-largest economy in just 40 years and has maintained high growth all year round is due to the development model of socialism with Chinese characteristics. The realization of a highly concentrated industrialization and urbanization process through the nationwide incremental land expansion movement is an essential support for China's ultra-high social and economic growth. Therefore, it can be seen that in the 2000s, after China entered the WTO, many domestic and foreign studies on urban China focused on researching spatial governance under the "growth orientation" [3]–[8]. For example, the critical findings of "Growth Machine", "Growth Coalition" [9], [10], "Urban Regime Theory" [11] and "Re-scaling Theory" [12] are introduced from American urban studies in studying urban China, as well as the urban studies on European cities, such as the perspective of "Entrepreneurialism", "Good Government vs. Good Governance", and "New Public Management". These studies focus on the central–local relationship, inter-government relationship, government–enterprise relationship, and other dimensions of Chinese characteristics in the urban movement. It demonstrates the applicability of the neoliberal approach in the spatial governance of socialist countries. Also, it refines the characteristics of the neoliberal space governance path with Chinese characteristics under the growth-oriented development discourse, including "State Entrepreneurialism" [13], "(pro-) Growth Coalition" [5], and "Government–Enterprise Coalition" [14].

It can be seen that whether it is the construction of new cities or the renewal of old cities, the paths and movement patterns, as well as a governance mechanism in China's urban space during the period of "growthism", are based on the core benefit distribution of exchange values from commercialized urban land. The so-called "old city renewal" is based on the same "(pro-) Growth Coalition" organization (government and real estate developers) and the same incremental construction model ("massive demolition and construction" and "land appreciation income") under different policies. There are only minor differences in the construction of the new city, such as different geographical locations. Therefore, China's ultra-high-speed urbanization process has also witnessed the destruction of many historical urban areas, buildings' demise, and communities' disappearance. These are not conducive to the future sustainable development of Chinese cities. In the new era, with the gradual development of the national power-led "Urban Renewal Action" strategy, the emergence of new arguments, such as "protecting historical and cultural values" [15], "people-centered urban development" [16], and "prohibiting large-scale demolition and construction" [17] all require in specific projects. It pushes local governments to change the extensive incremental path of real estate in the past, and explore the new path of urban renewal that is satisfactory to the people and needs of the times. From the few new practices in Shanghai, Nanjing, and Guangdong, it is found that this new path is the "Urban Micro-Renewal" (*weigaizao*) [18], which bases on the reorganization of existing property rights and constructs based on the willingness of property owners. The practice of the new model has made a significant breakthrough in the value orientation and governance mechanism of the government–enterprise "Growth Coalition" and real estate path used in urban development in the past. It

brings new insights into the deepening of related research on urban spatial governance in urban China and theoretical update. The academic significance also brings guiding significance for further improving the practice path with new academic research.

2 RESEARCH METHODOLOGY AND CASE SELECTION

2.1 Research methodology: Pluralism and Urban Regime Theory

The development of urban governance research mainly comes from analyzing two central concepts, namely the struggle between elitism and pluralism [19]. In the 1950s, influenced by the strong demand for urban reconstruction after World War II, urban space became an essential container for regulating social development. At that time, research on spatial governance focused on how to control and organize society. Therefore, the earliest research focused on the question of "who rules" in the spatial governance system, and two theoretical camps (elite-dominated and public-dominated) emerged, respectively. With the rise of neoliberalism in the 1970s, a large number of emerging market forces entered the urban governance mechanism ruled initially by political elites, and the theory of the "urban growth machine" emerged [10], [20]; in the 1980s, the non-economic value has been significantly improved, and a large number of diverse values and subjects have participated in urban spatial governance. The "Urban Regime Theory" (URT) representing pluralism has further developed into a fundamental theory for studying urban spatial governance mechanisms based on absorbing the former pluralism theories [11]. Therefore, after China has guided plural values into the overall context of urban development through policies in the past ten years, this paper believes that it has particular applicability to use the URT representing pluralism to analyze the current governance mechanism of Urban Micro-Renewal.

URT generally believes that the spatial production of cities is controlled by a governance mechanism (that is, "regime") composed of three forces: government, market, and social. While its academic research focuses on how to effectively integrate the three forces to achieve the maintenance and stability of the regime in urban development. Stone, as a master of the theoretical research on URT, divides it into "maintenance regime", "development regime", "middle-class progressive regime" and "lower-class opportunity expansion regime" according to the different effects of the three forces operating in urban spatial governance [11]. The integration of government and market forces to form a development regime can well explain the characteristics of governance mechanisms such as the "urban growth machine" or "social cybernetics" in the industrial age [19]. Many existing studies on urban spatial governance in China during rapid development are mainly analyzed from such perspectives. With the continuous influence of economic globalization and the rise of civil society, the research pays attention to the spatial production model and the redistribution of the multi-value resources such as wealth, employment, and culture in spatial production. However, there is a lack of relevant research on China from such a perspective. The reasons that, on the one hand, China is just in the initial stage of a new transformation, and there is still a "growth-oriented" path dependence in local practice; on the other hand, under the long-term influence of the "growth orientation", civil society forces are relatively lacking, which needs practice and time to correct. Therefore, when using the three-dimensional perspective composed of government, market, and social forces in the URT to analyze the practical cases of urban micro-renewal in China, this paper pays special attention to the different urban regimes from the traditional (pro-) growth coalition, and the evolution characteristics of the new regime under the guidance of plural values, and the relevant changes in the type of urban regimes in the overall process.

In addition, this paper uses long-term semi-structured interviews with the competent Planning Bureau, Housing and Urban–Rural Development Bureau, Economic and Information Bureau, Housing Administration Bureau, Culture and Tourism Bureau, and state-owned platforms in the Southern Part of the Old City of Nanjing (SPOCN) to obtain critical analytical data. Taking qualitative analysis as the primary method, it empirically analyzes the changes in the urban renewal regime in the SPOCN.

2.2 Case selection: Southern Part of the Old City of Nanjing

Nanjing is the capital of Jiangsu Province on the east coast of China, and together with Shanghai and Hangzhou is the central city in China's most important Yangtze River Delta Region. Nanjing, as one of the first state-list famous historical and cultural cities in China, has a civilization history of 7,000 years and has been the capital of China six times in history. SPOCN (Fig. 1) was built in the Six Dynasties (222 years) and revived in the Southern Tang Dynasty (937 years). It has always been a gathering place for urban civilians and business people, with profound folk culture and commercial culture, and is regarded as the birthplace of Nanjing's urban space and culture [21].

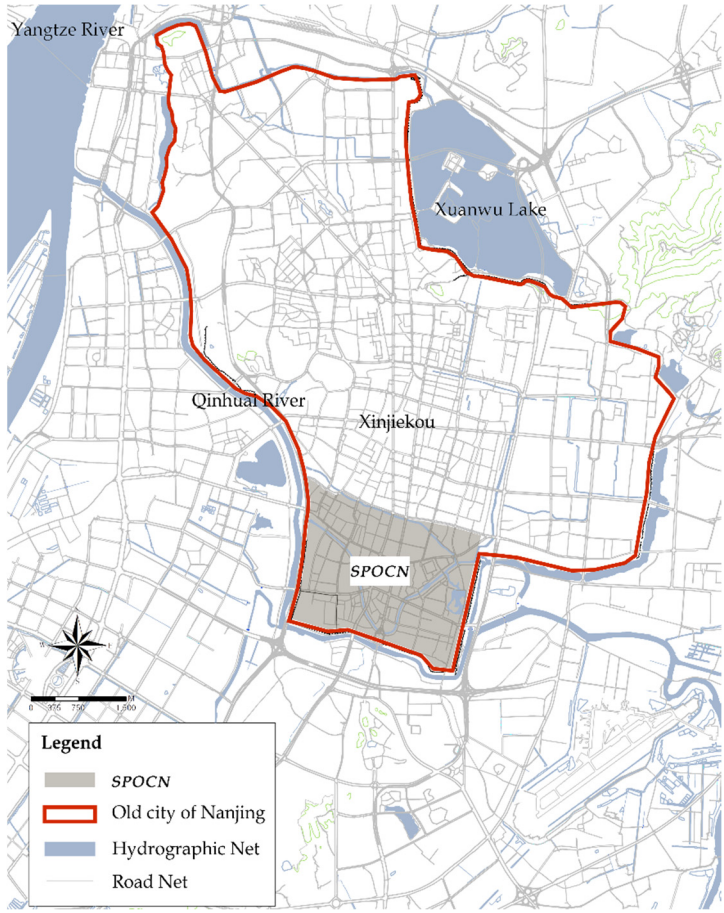

Figure 1: Location of SPOCN in city of Nanjing. *(Copyright by Authors.)*

There are three main reasons why the SPOCN is chosen as the case site for this article to analyze the micro-renewal of Chinese cities in the new era: (1) Nanjing is one of the 11 pilot cities in the new strategy of "Urban Renewal Action". (2) Compared with the foreign-investment dependence of Shanghai, policy dependence of Beijing, and financing dependence of Guangdong, Nanjing does not rely too much on a particular means of production but is more or less affected by these all. Therefore, Nanjing could represent the most typical common cities in mainland China. (3) SPOCN has been the most important regeneration of the Old City of Nanjing since the early days of reform and opening up. It has participated in the urban renewal movement in China in different eras and contexts, which can reflect the governance characteristics and changes in the "micro-renewal" movements. Therefore, it can fully support the research on the urban spatial governance mechanism changes and contribute to the existing findings on URT in China.

3 THE RESCALING OF URBAN REGIME IN SPOCN

The urban renewal of SPOCN began with the state land and housing marketization reform in the 1990s. With the commercialization of the two, the exchange value surrounding the land market was gradually discovered and operated on a large scale. In general, the urban regime in the process of urban renewal in SPOCN has undergone three necessary rescaling processes: (1) From the 1990s to 2005, the reconstruction of ancient areas under the Development Regime with deeply aligned government and market forces. (2) From 2006 to the 2010s, the "SPOCN Incident" marked the rise of urban cultural elites' awareness of protecting the old city and formed a Middle-Class Progressive Regime under the alliance of social forces and government forces. (3) From the early 2010s to the present, it has formed a Lower-Class Opportunity Expansion Regime with the alliance of government and social forces and the return of "people-oriented" plural values.

3.1 Rapid growth: Reconstruction under Development Regime

3.1.1 Massive demolition and reconstruction

In 1992, Nanjing promulgated the "Reform of Housing System", which promoted the rise of Nanjing's real estate industry, and a large amount of market capital entered the construction of urban infrastructure and the built environment. Subsequently, in 1995 and 1998, Nanjing adopted policies to stimulate the further development of the real estate market, put forward the urban construction goal of constructing 100 high-rise buildings in the main city, and formed the construction model of "replacing dwellings with roads (*yilu daifang*), offsetting the construction cost of roads by the exchange value of dwellings (*yifang bulu*), and offsetting the construction cost of roads by the exchange value of lands (*yidi bulu*)" [22]. During this period, more than 20 billion yuan of the government budget was invested in regenerating old cities such as roads, housing, and infrastructure. Many old urban landscapes in SPOCN were replaced by skyscrapers, commercial housing and commercial blocks with modern scenes, to meet the general requirements for urban landscape upgrading in the early 2000s.

"Massive demolition and reconstruction" were a standard method for the regeneration of SPOCN during this period. Its rapid transformation efficiency and simple method of an overall replacement of property rights significantly improved the city's overall image for a while and was greatly supported by the government, enterprises, and even the general public. The Confucius Temple, Zhongshan South Road, both sides of Zhonghua Gate, Mendong District, Taiping South Road, Sanshan Street, Santiaoying, Nanpu Hall, Ganxi's Former Residence, and other well-known attractions in SPOCN were all demolished and rebuilt at that time. SPOCN, composed of traditional Jiangnan streets and residential houses, has been

replaced by new buildings and fake antiques, such as large shopping malls and commercial historical blocks. However, it has also completely changed the reality of the dilapidated appearance of the SPOCN and improved the city's overall appearance.

3.1.2 The alignment of government and market forces

The deep alliance between government and market forces has formed a "growth coalition", which is the governance basis for the rapid promotion of landscape renewal in SPOCN during this period. The government and real estate developers formed a "Development Regime", centering on the redevelopment of land operations and the redistribution of exchange value (Fig. 2).

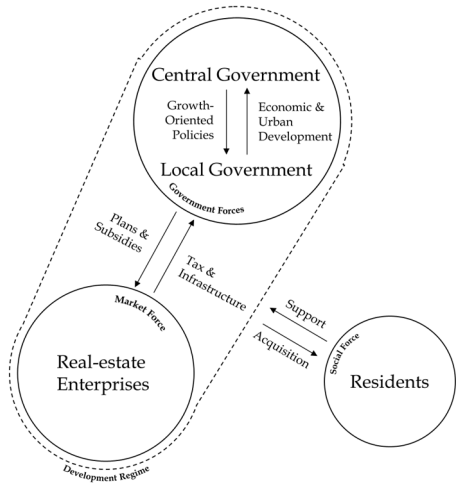

Figure 2: Development Regime in SPOCN under rapid growth discourse. *(Copyright by Authors.)*

The organization, policy, and planning of land incremental binding are the primary means for the government to promote the practice and attract market power in a "Development Regime". First, in the face of the fundamental problem of the lack of an exchange value market mechanism caused by the massive public ownership of urban land in China, the Nanjing Municipal Government promulgated two rounds of significant housing system reforms from 1992 to 1998 to provide legal support for land and housing. Secondly, the Nanjing Municipal Government has further revised the "Administrative Measures for the Demolition of Urban Houses in Nanjing", established a "Demolition Management Office", legalized the nature of the urban expropriation demand of "due to the needs of urban construction", and moderately reduced the needs of individuals during the demolition process. Finally, by compiling and revising the key indicators that can promote incremental urban transformation in the Development Control Plan of the SPOCN, such as the change of land use from residential to commercial or the increase of plot ratio. It successfully guided the massive demolition and reconstruction movements in SPOCN at that time.

The return of land value income and the internalization of supporting infrastructure are the endogenous driving force for real estate enterprises to form a market force and accelerate spatial production in the "Development Regime". Behind the government's vigorous efforts

to remove the institutional barriers of "demolition and reconstruction" is the appeal for the financial benefits generated by the exchange value of urban land. However, as urbanization brings many new urban populations, there is a real need to provide a more significant amount of urban infrastructure and housing supply. For these multiple reasons, real estate was regarded as the mainstream urban renewal path then, and real estate enterprises became the core market force in this Development Regime. Through an effective alliance with the government, it has monopolized urban land's primary and secondary development. In most areas of Nanjing, including SPOCN, many demolition and reconstruction projects are undertaken by real estate companies supported by the government. The government obtains land value income through land procedures of "bidding, auction, and listing", and returns 17% of it to real estate companies as tax subsidies. While real estate companies were responsible for the infrastructure investment and construction in real-estate development projects for exchange. In this way, the government obtained considerable fiscal revenue and released some pressure on public services and facilities. Such a smooth and reasonable alignment path significantly accelerated the "Development Regime" spatial practice during this period.

3.2 Against growth: Protection under middle-class progressive regime

3.2.1 SPOCN incident and reconstruction guerrilla

From the 1990s to the early 2000s, the efficient alliance of government and market has damaged a large number of historical buildings and blocks in SPOCN. In 2006, five historic districts along the Qinhuai River, including Pigment Square, Diaoyutai, Chuanbanxiang, Mendong, and Anpin Street, in SPOCN, were listed as new demolish missions, which made cultural scholars and aborigines vehemently oppose. They believed that it is a disaster for Nanjing and even the Chinese nation's cultural heritage. Therefore, Wu Liangyong, Xie Chensheng, and other 16 significant intellectuals in China drafted the article "Urgent appeal for preserving Nanjing's Historic Old Town" [23] to the Premier of the State Council, hoping that high-level forces would intervene to restrain local sabotage. This is the "SPOCN Incident".

With the intervention of the central forces in the local demolition and reconstruction behavior, a "guerrilla war" was staged in SPOCN for the four years from 2006 to 2010. The central government proposed to the State Administration of Cultural Heritage, the Jiangsu Provincial Government, the Legislative Affairs Office, and other relevant authorities to revise the new requirements for the protection of historical and cultural cities and put pressure on the Nanjing local government through vertical administrative management. In the face of heavy pressure from the top, the Nanjing local government decided to take an initial roundabout tactic. On the one hand, the local government of Nanjing went to Beijing many times to report the progress of renewal movements in SPOCN and responded to the pressure from the upper level with the new "16-character" renewal policy of "Overall protection (*zhengti baohu*), Organic renewal (*youji gengxin*), Government-led (*zhengfu zhudao*), and cautious use of the market force" (*shenyong shichang*). On the other hand, in the face of the urgent land demand and financial pressure on the local development, the demolition and rebuilding of the old city were still promoted in the form of the "Development Regime". While waiting for the "SPOCN Incident" to stabilize slightly, the Nanjing local government once again promoted a new round of demolition in SPOCN. In 2008, eight districts of Nanjing in the southern area of the Yangtze River launched a large-scale housing regeneration and replacement. The only remaining four historical sites in SPOCN (Nanpu Hall, Mendong, Menxi, and Cangxiang) were once again included in the scope of the

demolition and reconstruction project. In April 2009, 29 cultural personnel in Nanjing again alerted the State Council's Prime Minister with a letter of "Urgent protection of Nanjing historical and cultural city" [24]. In this way, the central government has increased the degree of administrative intervention and dispatched a central monitoring team to the SPOCN to stop the demolition and replacement movements.

3.2.2 The alignment of social and upper government forces

Through the well-known "SPOCN Incident", a social force composed of the middle class represented by the urban cultural elites took the initiative to intervene in the local renewal behavior. With the support of the central high-level government in a way that crosses the administrative level. The "Development Regime" that was popular in the previous renewal process has evolved into a "Middle-Class Progressive Regime" (Fig. 3).

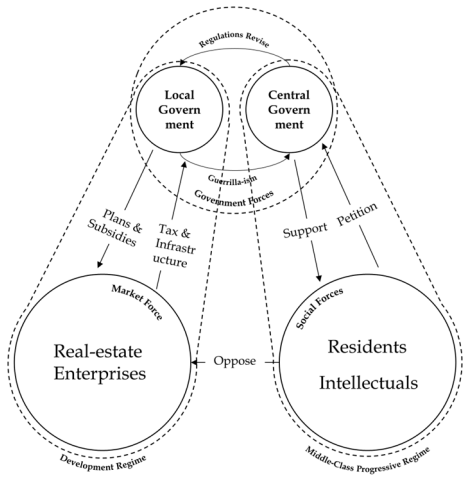

Figure 3: Middle-Class Progressive Regime in SPOCN under Anti-Growth Discourse. *(Copyright by Authors.)*

The static protection of the cultural, spiritual, material, and other diverse values contained in the historical heritage of SPOCN is the core driving force for social forces to intervene strongly and oppose the original "Development Regime". The rise of the social force composed of cultural elites is an anti-growth force formed by the folk from the "bottom-up" after suffering colossal damage caused by the "growth-oriented" development. Using Polanyi's "Two-way Motion" theory, the dynamic logic behind such phenomena can be well explained. A large number of market stimulation mechanisms formed in the "rapid growth stage" in SPOCN make the market forces. But at the same time, the active protection of social factors such as nature and culture issues also form a balancing force against the market's laissez-faire development.

Successfully crossing the administrative management level and gaining strong support from high-level government forces are the critical factors for the "Middle-Class Progressive Regime" to form the "anti-growth" protest movement in SPOCN. It is difficult for a single social force to intervene in the government-led urban development process, especially in China's strict administrative hierarchy and policy-oriented urban governance mechanism. On

the contrary, China's unique inter-government management system effectively enables social forces to intervene in local development through higher-level government forces. However, nor are all "bottom-up" protests able to alarm the central government. The social force in the "SPOCN Incident" represents the top intellectual group in China's current society, and only then can higher social resources be used to exert the restrictive role of social force in the urban governance mechanism.

3.3 Beyond growth: Micro-renewal under Lower-Class Opportunity Expansion Regime

3.3.1 Dilemma: Both depressions of population and landscape

The governance of urban renewal movements in SPOCN has experienced the "Development Regime" and the "Middle-Class Progressive Regime", respectively, which has brought an embarrassing dilemma to the actual situation of the historic area. On the one hand, from the 1990s to the early 2000s, only about 10% of the Old City of Nanjing was left under the rapid advancement by the "Development Regime". On the other hand, the "Middle-Class Progressive Regime" overemphasizes the static material protection of historic heritage and cultural relics. As a result, although SPOCN has experienced ten years of stability, it forms a strong contrast with the surrounding bustling urban landscape.

After the SPOCN Incident, the only remaining historic district has gradually become depressed in population and urban landscape as the forgetting time. Under the "Middle-Class Progressive Regime" intervention, the government has accelerated the formulation of policies and plans related to historical and cultural protection. The "Regulation on the Protection of Famous Historical and Cultural Cities, Towns and Villages" have been formed across the country, and the old city area of Nanjing has formed a protection grading system. SPOCN has also stepped up the preparation of the "Preservation Planning and Urban Design of the SPOCN". On the one hand, this series of new governance forces centered on protecting history and culture by controlling indicators such as height limit, floor area ratio, and land use limit. These have strongly protected the only remaining historic blocks in SPOCN, however, caused the exclusion from the incremental development process of the city for many years. Continuous decline has turned the initially prosperous SPOCN into a landscape depression in the center of Nanjing. For example, the quality of life in the designated historical districts is in the frozen time of 1980s. Most residences lack independent facilities such as kitchens, toilets, and showers. On the other hand, the decay of physical space also forced many aborigines to move out of SPOCN due to their longing for a better quality of life. While cheap rents and a decaying environment have attracted a large influx of lower-class residents over time. Through visiting and investigating the historical areas such as Xiaoxihu, Hehuatang, and Diaoyutai in SPOCN that have not been renewed, it is found that the population structure of these areas is dominated by low-income households, prisoners of labor reform, the elderly, and other urban vulnerable groups.

3.3.2 Process: Stay, adapt or demolish by willingness of vulnerable groups

Facing the contradiction between the increasingly strict protection of historical urban areas and the increasingly severe living environment of the old city, the renewal paradigm must be transformed to bring hope to these urban depressions. Whether it is the "massive demolition and reconstruction" guided by the previous "Development Regime" or the static protection guided by the "Middle-Class Progressive Regime", neither is an excellent way to change the double depression of population and landscape, which needs innovation.

The needs of the vulnerable groups are the core content of the new renewal plan in SPOCN, and it has evolved into the new renewal procedure of "Stay-Adapt-or-Demolish"

rather than direct "Demolition–Reconstruction". Taking the Dayoufang project as an example, a large amount of social work was placed at the beginning of the project, communicating with 810 aboriginal households in the plot for one year. The project finally formed the content of the detailed plan in which 402 households chose to keep the original property rights, and 408 households chose to relocate and exchange their original property. Most of the 402 aboriginal households who choose to retain the property rights are in the form of private dwelling (*Sifang*). Under the overall positioning of no demolition, the renewal plan provides many new ideas for how to stay and in what form to update by holding design competitions and other methods. Therefore, in the specific practice of the project, the adaptive reuse of old buildings such as "shared courtyard" and "community cafe" appeared. In the face of 408 households who chose to relocate, the new model did not adopt a one-size-fits-all approach to suburban resettlement as before but went deeper into the types of residents. According to the different properties of public housing, private housing, and unit housing, as well as the living and economic conditions of the residents themselves, the new plan formulates three types of options: "translational resettlement", "nearby resettlement", and "suburban resettlement". For the buildings left by the aborigines after the relocation, the district government, design, and development companies shall purchase and protect them or demolish them for other purposes according to the requirements of historical protection. Overall, the relocation released 48 building spaces (including preservation and demolition), all of which were used to improve the quality of public space in the neighborhood and stimulate the vitality of traditional blocks.

Governments' active transformation of the real estate-led market force is the objective factor in ensuring the emergence of a "Lower-Class Opportunity Expansion Regime" in SPOCN (Fig. 4). In the previous "Development Regime", the market power composed of real estate enterprises could join voluntarily because of the value surplus in the operation of the urban land. However, in the face of the "SPOCN Incident" and the new development melody from the central government, the Nanjing Municipal Government proposed a new strategic orientation for "cautious use of market force" (*shenyong shichang*). This has

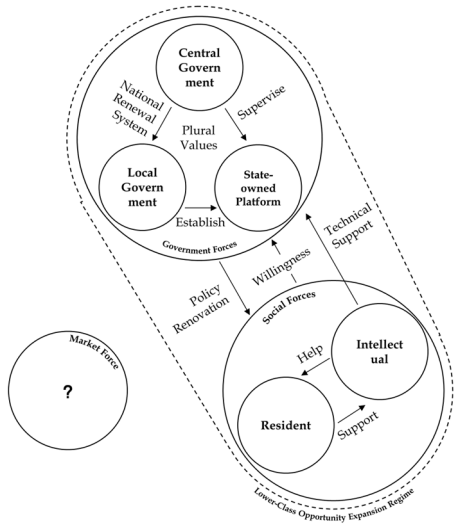

Figure 4: Lower-Class Opportunity Expansion Regime in SPOCN under Beyond Growth Discourse. *(Copyright by Authors.)*

dramatically reduced the residual value in the land operation. As the most profit-seeking market force, it is impossible to participate in a micro-renewal activity such as Dayoufang. Therefore, government forces began to integrate the real estate enterprises scattered in the market but with a government nature through the state-owned platform. It re-incorporated them into the government agencies through the State-owned Assets Supervision and Administration Commission. This ensures the smooth implementation of the "Stay-Adapt-or-Demolish" micro-renewal method centered on considering the vulnerable groups' living and livelihood needs.

3.3.3 Result: "Good film, but small audience"

For a while, the Dayoufang project has received unanimous praise from all walks of life in Nanjing, the media, and the central government. After extensive publicity by various media, the government's image, which was previously labeled as "violent demolisher", has been completely changed. At the same time, the domestic architectural academic journal *Architect* also specially organized an academic interview to discuss the new micro-renewal method in SPOCN. However, if we look at the new paradigm under the guidance of the "Lower-Class Opportunity Expansion Regime" in SPOCN from a more objective and rational perspective in reality, it creates a strange circle of "Good film, but small audience" (*jiaohao bujiaozuo*).

From the perspective of the government and the public, the micro-renewal paradigm in SPOCN has indeed largely solved the longtime difficulties of the dilapidated appearance and brought opportunities to vulnerate groups in the historic district. It is a triumphant work for people's livelihood and public services. However, from the perspective of sustainable replication and promotion of the project, the micro-renewal model that appears on the surface has the embarrassing situation of the infinite investment from the government side. It still has the color of planned distribution under the strong spatial Keynesianism, which increases the pressure on the fair redistribution of government finances and public welfare. In particular, establishing a state-owned platform to incorporate government enterprises pushes away the market force in the renewal movement (Fig. 4). It causes Vanke and other large enterprises and NGOs cannot enter the urban renewal market in Nanjing. The core of the contradiction is that the micro-renewal paradigm does not generate surplus value or new value that can attract or create new market forces, and there is a stage dilemma of sustainable promotion.

4 THE POWER SHIFTS OF URBAN REGIME IN SPOCN

Based on the trinity framework of government force, market forces, and social force in the URT, this paper analyzes the transformation of the urban renewal governance model in SPOCN since the 1990s. It finds that under the combined effect of different era policies and internal contradictions, its governance model has changed from "Development Regime", "Middle-Class Progressive Regime", to "Lower-Class Opportunity Expansion Regime". The internal driving force for this transformation comes from the successive shifts of government, social, and market forces in facing new development discourses.

4.1 Transformation of government force: Coordinated development of plural values

Government power is the main driving force for the change of the urban regime in the renewal process of the SPOCN, and it also reflects the change in the government's values of the renewal and the production of urban space under the development discourses of the new era. In the context of the 1990s, continuous reform and opening up created a "growth-oriented" urban expansion strategy across the country. Therefore, in the early reconstruction of

SPOCN, the government regarded urban land and space as the critical carrier to promoting growth. The role of government was to focus on breaking the institutional barriers that hinder the rapid circulation of growth factors. With the deepening of marketization, the highly compressed urban development process has exposed many social problems that damage the ecological and human environment, which led to the awakening of internal social forces to balance the disorderly expansion of the market during the renewal process of SPOCN in the early 2000s. However, local government force was highly dependent on the growth path, and its acceptance and integration of new values initially showed resistance and coping, making it appear to be a common differentiation phenomenon in the early stage of transformation. While with the recent high-level government's correction of plural values such as culture, ecology, history, landscape, and humanism in urban development, local governments have also taken the initiative to start a new round of transformation and exploration of governance models. The government force in this period differed from the "growth-oriented" period, turned to serve multiple values and people-oriented governance exploration. However, there has also been a staged dilemma of blindly pursuing political achievements and disregarding costs.

4.2 Expansion of social force: The gradual return of people-oriented value

The changes in the urban regime in SPOCN have witnessed the evolution of social forces in China's urban renewal governance, from the marginalization of the discourse system to the centralization. It has also witnessed China's unique form of an anti-growth coalition between senior intellectuals and high-level governments. Under the influence of the "growth orientation" formed since the 1990s, because of lacking production factors, social forces are often in a weak position in the old city renewal governance system. The owners who make up the social force are often passively arranged by the system and the market, being resettled far away from the urban area. However, with the improvement of the quantity and quality of intellectuals, the non-economic values of culture, history, ecology in urban construction have been continuously strengthened in social consciousness. The progressive values representing the middle class began to speak in the governance of the old city renewal, forming the initial form of social force. Universities and experts have joined in formulating urban renewal plans, ensuring it is no longer just a tool for profit-seeking under the coalition of government and market forces. With the re-recognition of cultural, ecological, social, and other non-economic values in urban space by the central government, the relatively vulnerate groups and residents have returned to the core position of governance, realizing the proper return of people-oriented values in social forces.

4.3 Withdrawal of market force: The continuous decline of economic value

The market power of real estate enterprises was the main body for implementing most of the old city reconstruction in SPOCN. After forming a real-estate growth machine with government forces, market forces not only provide new living space for the old city but also provide infrastructure support. However, with the transformation of government forces and the continuous strengthening of social forces in the reconstruction of SPOCN, the plural values of space, such as the use-value, cultural value, and historical value, have gradually surpassed the exchange value surrounding the operation of land and space. Therefore, urban micro-renewal projects in SPOCN are all undertaken by government developers on the government's state-owned platform. Moreover, developers with market capital have selectively withdrawn from many community, historical and residential renewal projects.

The most significant difference between government developers and market developers is that the investment funds of government developers come from the government's fiscal or fiscal transfer revenue. The essence of fiscal revenue is for general social service expenditures, not for improving the quality of life of a particular area or even some owners. Moreover, compared with the method of demolition, reconstruction, and re-sale, the micro-renewal based on the residents' willingness have very little profit, and it is impossible to achieve a balance of payments. This transformation has brought severe hidden dangers to the financial sustainability of old city renewal, and the efficient implementation of the micro-renewal paradigm requires further exploration.

5 CONCLUSION AND DISCUSSION

With the increasingly tense global environment and the new era of urgent transformation, China's urban development has officially entered the exploratory stage of new regime of urban regeneration. In the practice of Shanghai, Beijing, Guangdong, Nanjing, and other pioneering areas, micro-renewal project practices have different from the traditional growth-oriented demolition and reconstruction. They spontaneously changed the previous urban growth machine (aligned with government and market forces), and formed a new governance regime by government and social forces. This paper selects SPOCN in Nanjing City as the research object and analyzes the evolution process of this governance transformation and the changes of forces from the perspective of URT.

This paper finds that the renovation of the old city in the SPOCN, has experienced the changes in governance modes of "development regime", "middle-class progressive regime", and "lower-class expansion regime" in different contexts of times. Government force has played a leading role in this transformation process, showing distinct Chinese characteristics. Through the continuous evolution and improvement of its development concept, the government's understanding of urban space has gradually evolved from a single economic value that was "growth-oriented" in the past to a plural value composed of economic, ecological, cultural, historical, and social, and other people-oriented values. The changes of government forces has dramatically promoted the transformation of the local urban regime. The most noticeable feature is the continuous expansion of social force in the urban regime, from the marginalization in the early "Development Regime", to the intense confrontation in the mid-term "Middle-Class Progressive Regime", and then to the centralized position in the current "Lower-Class Opportunity Regime". It ensures that people-oriented values return to social forces and urban regime. The new renewal project governed by the "Lower-Class Opportunity Regime" has won unanimous praise from the public, believing that it is a new trend of future urban regeneration governance. However, in reality, such models have fallen into the problematic situation of "Good film, but small audience". The core contradiction is the regime's weakening or even the absence of traditional market forces. It brings enormous financial pressure to the government, and it has become a new era problem in the renewal of old cities, primarily residential and community types. Further research on related governance mechanisms and policies needs to address these issues.

It can be seen that this paper once again proves the applicability of the "Urban Regime Theory" with the characteristics of Western localism in the study of urban development with Chinese characteristics. It also exposes the inner laws of the government's ability to mobilize social and market resources to achieve a stable governance regime [25]. Meanwhile, this study also proves the absolute leading role of government forces in development and transformation of urban China.

REFERENCES

[1] Xinhua, Lucid waters and lush mountains are invaluable assets. https://www.chinadaily.com.cn/china/19thcpcnationalcongress/2017-10/09/content_33032118.htm. Accessed on: 30 Dec. 2021.
[2] National Development and Reform Commission (NDRC), Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China. https://www.fujian.gov.cn/english/news/202108/t20210809_5665713.htm. Accessed on: 30 Dec. 2021.
[3] Oi, J.C., Fiscal reform and the economic foundations of local state corporatism in China. *World Politics*, **45**(1), pp. 99–126, 1992.
[4] Zhu, J.M., Local growth coalition: The context and implications of China's gradualist urban land reforms. *International Journal of Urban and Regional Research*, **23**(3), pp. 534–548, 1999.
[5] Zhang, T.W., Urban development and a socialist pro-growth coalition in Shanghai. *Urban Affairs Review*, **37**(4), pp. 475–499, 2002.
[6] He, S.J. & Wu, F.L., Property-led redevelopment in post-reform China: A case study of Xintiandi redevelopment project in Shanghai. *Journal of Urban Affairs*, **27**(1), pp. 1–23, 2005.
[7] Qian, Z., Institutions and local growth coalitions in China's urban land reform: The case of Hangzhou High-Technology Zone. *Asia Pacific Viewpoint*, **48**(2), pp. 219–233, 2007.
[8] Hin, L.L. & Xin, L., Redevelopment of urban villages in Shenzhen, China: An analysis of power relations and urban coalitions. *Habitat International*, **35**(3), pp. 426–434, 2011.
[9] Molotch, H., City as a growth machine: Toward a political-economy of place. *American Journal of Sociology*, **82**(2), pp. 309–332, 1976.
[10] Logan, J.R. & Molotch, H.L., *Urban Fortunes: The Political Economy of Place*, University of California Press: Berkeley, CA, 1987.
[11] Stone, C.N., Urban regimes and the capacity to govern: A political-economy approach. *Journal of Urban Affairs*, **15**(1), pp. 1–28, 1993.
[12] Brenner, N., New state spaces: Urban governance and the rescaling of statehood. *OUP Catalogue*, **82**(1), pp. 113–114, 2004.
[13] Wu, F., Planning centrality, market instruments: Governing Chinese urban transformation under state entrepreneurialism. *Urban Studies*, **55**(7), pp. 1383–1399, 2018.
[14] Sun, X. & Huang, R., Extension of state-led growth coalition and grassroots management: A case study of Shanghai. *Urban Affairs Review*, **52**(6), pp. 917–943, 2016.
[15] Xi, J., Speech at a ceremony marking the centenary of the Communist Party of China. *The 100th Anniversary of the Founding of the Communist Party of China, Beijing*, pp. 1–14, 2021.
[16] Xi, J., Xi Jinping: A city is a city for the people, and a city for the people is for the people, *People's Daily Overseas Edition*, 2019.
[17] Ministry of Housing and Urban–Rural Development (MoHURD), Notice of the Ministry of Housing and Urban–Rural Development on preventing major demolition and construction in the implementation of urban renewal action. http://www.mohurd.gov.cn/gongkai/fdzdgknr/zfhcxjsbwj/202108/20210831_761887.html.

[18] Wu, F., Zhang, F. & Liu, Y., Beyond growth machine politics: Understanding state politics and national political mandates in China's urban redevelopment. *Antipode*, **54**(2), pp. 608–628, 2021.
[19] Stoker, G. & Mossberger, K., Urban regime theory in comparative perspective. *Environmental and Planning C: Government and Policy*, **12**(2), pp. 195–212, 1994.
[20] Harvey, D., From managerialism to entrepreneurialism: The transformation in urban governance in late capitalism. *Geografiska Annaler*, **71**(1), pp. 36–53, 1989.
[21] Chen, H., Zhang, J. & Lin, C., Anti-growth politics in urban spatial development: A case study on the Southern Old City event of Nanjing. *City Planning Review*, **39**(4), pp. 19–26, 2015.
[22] Li, X., Old town renovation in Nanjing during the past 30 years: Based on the case study of urban renewal process. School of Architecture, Southeast University, Nanjing, 2016.
[23] Yao, Y., Urgent appeal for preserving Nanjing's Historic Old Town. *The Consciousness of Cities,* eds S. Xu & Y. Wu, pp. 142–146, Beijing University: Beijing, 2015.
[24] Yao, Y., The protection of Nanjing's historical and cultural city is urgent. *The Consciousness of Cities*, eds S. Xu & Y. Wu, pp. 157–161, Beijing University: Beijing, 2015.
[25] Stone, C., The Atlanta experience re-examined: The link between agenda and regime change. *International Journal of Urban and Regional Research*, **25**(1), pp. 864–889, 2001.

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UNIVERSAL DESIGN APPROACH TO A SMART, SUSTAINABLE, SAFE, AND ACCESSIBLE CITY FOR ALL

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ABSTRACT

Sustainable cities are one of the economic development elements in architecture and urban development, more than half of the world now resides in urban areas. Furthermore, the advancement of technologies such as artificial intelligence creates smart cities to improve urban integration. However, an essential aspect of sustainability that is absent is the inclusion of the elderly and the disabled in the community. It serves as one of the markers of modernity. Rather, it is a prerequisite for developing our cities, making them more sustainable, intelligent, safe, and accommodating to all society segments and achieving equality. Sustainability is not affected by persons, and environmental justice is as important as sustainable development. People with disabilities and the elderly constitute a large proportion of society and this is expected to rise in the upcoming years. Despite widespread support for the inclusion of people with disabilities in society, they were not considered during the design process. Society only sees the able-bodied; therefore, we must link technology and use universal design principles and integrate them with sustainability standards. As a result, the research aims to create an inclusive city and identify barriers to universal design through developing an objective approach framework and a new evaluation method, research was used to generate data by example analysis of various buildings, developing a new design approach of universal design, involving users, experts, people with disabilities, elders, designers, and stakeholders to solve problems with a focus on the city of Alexandria and evaluate it. The paper concludes by speculating about the part that designers can play in implementing a more inclusive design approach to be accessible for all. A society is not smart, sustainable, or secure if it is not accessible.

Keywords: Alexandria, smart, safe, sustainable, accessible city, sustainability, universal design, accessibility, disability, elderly.

1 INTRODUCTION

Alexandria has grown to be the largest city in the Mediterranean region, it covers an area of 2,679 km^2 of the total area of Egypt, 1,002,000 km^2, about 0.26% of the total area. Its population is 5,422,608 out of a total of 101,463,702, about 5.3% of the total population. Due to its prominent location, it is home to numerous attractive beaches, historic museums, and other tourist destinations that draw significant numbers of visitors. as well as an ancient street that stands witness to the history of the Mediterranean bride to paint a wonderful painting in one of the oldest streets in the world, it is Fouad Street, the most famous street of Alexandria, famous for the presence of many heritages' ancient buildings, theatres and cinemas in addition to museums such as The Greco-Roman Museum and Alexandria National Museum.

The Central Agency for Public Mobilization and Statistics revealed that the percentage of people with special needs represents 10.5% of the total population in Egypt, and indicated that the difficulty of walking or climbing stairs came first, followed by hearing difficulties, vision difficulties, and another type of disabilities, as well He revealed that the number of elderly people in Egypt between the ages of 60 and 70 has reached about 6% of the total population, and this percentage is expected to rise to 17.9% in 2052 [1].

So, the research focuses on how to make a sustainable accessible city for people with disabilities and elders and can be finding and presenting simple and small solutions to solve the potential problems that result from Architectural disability, exploration of elders and disabilities problems to explore design approaches that are suitable for all.

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1.1 Research problem

There is a missing part in sustainability which is the participation of people with disabilities and the elderly in the community, despite they constitute a large proportion of society So, one of the reasons for the major problem is architects' lack of deep understanding of the need of the elder and disabilities.

Table 1: Number of people with disabilities in Egypt and Alexandria in 2017 [1].

	Total population		People with a disability		% of disabilities
	Males	Females	Males	Females	
Egypt	42,297,930	42,297,930	4,596,601	4,039,929	
	81,897,253		8,636,530		10.5
Alexandria	2,337,155	2,200,652	308,485	266,527	
	4,537,807		575,012		12.6

Table 2: Number of elderly people over 60 according to gender and age in 2006 [1].

Age group	Males		Females		Total	
	Number	% of total pop.	Number	% of total pop.	Number	%
60	899,287	1.2	806,215	1.1	1,705,502	2.3
65	641,051	0.9	552,549	0.8	1,193,600	1.7
70	402,489	0.6	387,403	0.5	789,892	1.1
75+	376,730	0.5	362,034	0.5	738,764	1
Total	2,319,557	3.2	2,108,201	2.9	4,427,758	6.1

Table 3: Number of elderly people over 60 according to gender and age in 2017 [1].

Age group	Males		Females		Total	
	Number	% of total pop.	Number	% of total pop.	Number	%
60	1,416,589	1.5	1,232,771	1.3	2,649,360	2.8
65	942,610	1	777,591	0.8	1,720,201	1.8
70	531,050	0.6	484,900	0.5	1,015,950	1.1
75+	476,962	0.5	449,700	0.5	926,662	1
Total	3,367,211	3.6	2,944,962	3.1	6,312,173	6.7

1.2 Research aim

The Research aims to make a case for the sustainable development of Fouad Street, Alexandria, as the state aims to develop it by the inclusion of the elderly and the disabled in its Architectural Design by using the Universal Design Approach (UDA).

2 UNIVERSAL DESIGN DEFINITIONS AND PRINCIPLES

The mission of universal design is to create places and products that can be used by as many people as feasible without requiring specific adaptations or designs [2].

One strategy that encourages preserving social sustainability elements that ensure an equitable distribution of wealth and services both within and between generations is universal design [3].

Table 4: Universal design principles [4].

No.	Universal design principles
01	Equitable use: The design is useful and marketable to people with diverse abilities.
02	Flexibility in use: The design accommodates a wide range of individual preferences and abilities.
03	Simple and intuitive use: The use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
04	Perceptible information: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
05	Tolerance for error: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
06	Low physical effort: The design can be used efficiently and comfortably and with a minimum of fatigue.
07	Size and space for approach and use: Appropriate size and space are provided for approach, reach, manipulation, and use regardless of the user's body size, posture, or mobility.

3 SMART, SUSTAINABLE, SAFE, AND ACCESSIBLE CITY DEFINITIONS

A smart city is a locality that makes use of electronic and technological infrastructure, such as information and communication technology (ICT), to gather real-time data and insights, offer some crucial services, and address issues that affect the city's everyday operations, such as its public transportation, water and power supplies, and sanitation systems. The local government can then use this information to influence judgments about developing practical solutions to address these ongoing city issues, as shown in Fig. 1 [5].

Figure 1: Smart, sustainable, safe, and accessible city.

A sustainable city is one that can withstand the effects of climate change while minimising population vulnerabilities. The ideal sustainable city would be self-sufficient in energy, manage waste to produce electricity, have more environmentally friendly transportation, preserve green spaces, and properly manage and utilise its natural resources.

It would be a city constructed around the ideas of equality, education, and ecology. We'll examine the traits of sustainable cities below, along with suggestions for how you may help create a pristine, environmentally friendly metropolis, as shown in Fig. 1 [6].

The Safe City concept in Smart Cities offers a fresh approach for the government to create a city security system One strategy used to address the crime issue in metropolitan areas is the safe city concept, which is a component of the live concept of the city. In other words, Safe City is a concept for a community that makes use of technology to assist governments, communities, and companies in lowering the likelihood of crime and creating a setting where people feel secure and at home, as shown in Fig. 1 [7].

Accessibility is the idea of whether a good or service is usable by everyone, no matter how they come across it. Despite the fact that there are accessibility rules in place to help persons with disabilities, designers should nevertheless make every effort to include all prospective users in all use cases. Better designs for all are one of the clear advantages of doing so, as shown in Fig. 1 [8].

3.1 Development goals of sustainable cities

Making cities accessible, safe, resilient, and sustainable in ways that equally benefit people with disabilities is the focus of Sustainable Development Goal 11. Of the 6.25 billion people predicted to be living in urban areas by 2050, an estimated 15% will be persons with disabilities [9].

4 METHODOLOGY AND CASE STUDIES

4.1 Methodology

The main objective of this study is to provide a UD evaluation of building design. The Seven Principles of Universal Design are typically the foundation for several UD building feature evaluation methods. Concerns relating to the physical, senses, and cognition are addressed by these principles. literature review addressed societal issues and gave a general summary of several criteria, examples analysis, and comparison according to the standard codes.

4.2 Case studies

This study focuses on three buildings as case studies to be assessed in light of the UD concept. The chosen case studies were selected based on their significance for the users. The three case studies are Accessible beach of Alexandria (A), Alexandria National Museum (B), and Enabling Village by WOHA, Singapore (C), as shown in Tables 5 and 6.

Table 5: The code of the three buildings.

Building code	Building name
A	The accessible beach of Alexandria
B	Alexandria National Museum
C	Enabling Village by WOHA, Singapore

Table 6: The description of the score rating of the items.

Score rating	Description
4–5	Fully achieved Universal Design principles
2–3	Partially achieved Universal Design principles
0–1	Not achieved Universal Design principles

4.2.1 Universal Design buildings assessment

Table 7: Universal Design assessment of the buildings.

Criteria	Items		Item score /5		
			A	B	C
Size and space for approach and use	Entering				
	Entrance	Walking entrances	5	5	5
		Accessible entrances	0	2	5
		Sheltered accessible entrance	4	3	5
	Landing and boarding	Suitable seating	3	0	5
		Accessible sheltered	3	0	5
	Connection	Connections within the same structure	4	3	5
		Connection to the next-door building	0	0	5
		Connection between the building	3	0	5
		Linking of buildings and street	0	0	3
		Connecting a building to a park	0	3	5
	Parking	Parking space accessibility	0	0	5
		Accessible parking with a charging station for electric vehicles	0	0	5
	The score of UD for the entrance (out of 60)		22	16	58
Function and security	Circulation				
	Car parking	Car park paths	0	0	5
		Pedestrian crossings in the parking lot	0	0	4
	Circulation routes	A path connecting all areas and facilities	0	4	4
	Ramps	Warning surfaces	0	0	2
		Handrails on both sides	0	0	4
		Edge protection	0	0	5
		Ramp landings	2	0	5
	Stairs	Warning surfaces	0	4	2
		Handrails on both sides	0	1	4
		Edge protection	0	2	5
		Minimum tread width and maximum riser height	0	2	5
	Corridors	Minimum suitable width	0	5	5
	Lifts	Full achieved UD if it just ground floor	5	1	2
	Elevators	Full achieved UD if it just ground floor	5	0	2
	The score of UD for the circulation (out of 70)		12	19	54
Understanding	Wayfinding				
	Rest areas	Sufficient seats	4	3	5
		Seating layout	3	3	5
		Various heights of the adjacent seats	0	0	5
		Adjacent area with wheelchairs	4	2	5
	Location-searching				
	Signage	Maps at the main accessible entrance	1	4	4
		Signs with simple-to-understand pictograms with hearing systems	0	3	4
		Shapes, colours, patterns	0	5	5
	Front desk	Information counters located at a high enough location	0	2	5
	Services and toilets	A larger individual restroom	2	2	4
		Accessible sinks	1	0	2
		Restrooms with a mechanical hoist	0	0	3
		Accessible grab bars	0	0	2
		Accessible toilets	3	0	3
		Accessible circulation and suitable width	3	1	4
	The score of UD for the wayfinding (out of 70)		21	25	56

Table 7: Continued.

Criteria	Items		Item score /5		
			A	B	C
Social	Social and recreational	A mix of outdoor play and fitness facilities	0	3	4
		Multipurpose rooms	0	5	5
		Accessible drinking fountains and kitchenette	0	0	5
		Accessible table height	0	0	5
	The score of UD for social and recreational (out of 20)		0	8	19
	The total score of UD for all items (out of 220)		55	68	187
	Percentage %		25%	30%	85%

4.2.2 Over view and site analysis

1. The accessible beach of Alexandria is 230 m long, 90 m of which are for the disabled. walkway for the disabled has been developed, as it will be 12 m long and 2.5 m wide. Dedicate a special section for the blind, which includes specific paths within the water that allow the blind person to enjoy the sea without any problem, as shown in Fig. 2.

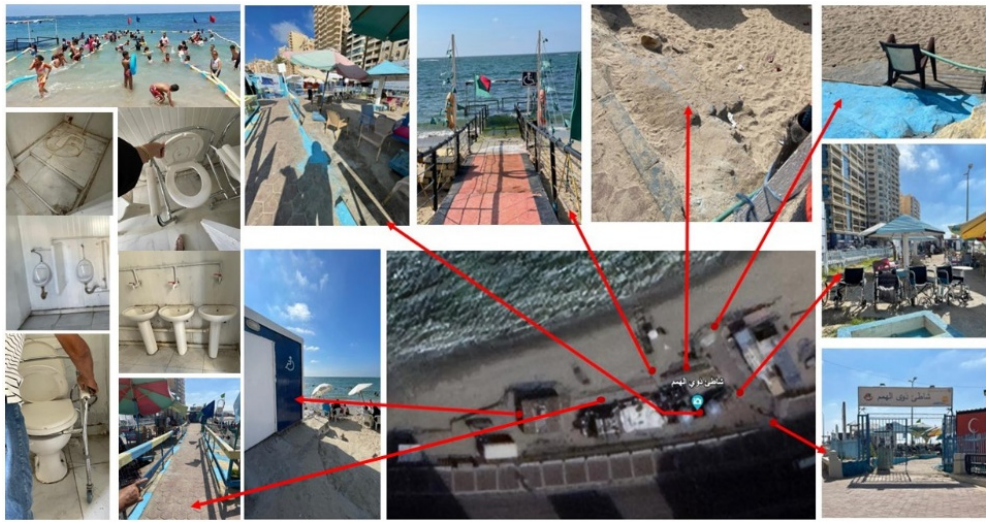

Figure 2: The condition of accessible beach analysis.

2. Alexandria National Museum is located in Foad Street and is the former residence of a prominent timber trading businessman, Asa'ad Basily. He constructed his villa in the Italian style. and it stretches over an area of 3,480 m. The palace was a popular gathering place for many of high-level people in the past century, particularly in the 1930s and 1940s, as shown in Fig. 3.

3. Enabling Village by WOHA, Singapore is known for being inclusive, The Enabling Village is a community centre, targeted to provide a better environment with the architecture. The new main building is anchored with the main pond that functions as a beacon to draw the pedestrian flow through improved linkages. The Enabling Village focuses on sustainability and sociability by promoting the learning, bonding, and healing of people with varying abilities [10], as shown in Fig. 4.

Figure 3: Alexandria National Museum analysis.

Figure 4: Enabling Village site [10].

4.2.3 Finding and results

1. Outdoor environment

Accessible routes: As shown in the figure the pavement width in building A and C is about 4.00 m and achieved the UD requirement according to national standard as the minimum clear width for a wheelchair user and a pedestrian to pass or walk beside each other is 1.80m.but pavement in building B is less than 1.00 m so that building doesn`t achieve the requirements, as shown in Fig. 5.

Crosswalks: As shown crosswalks' potholes and the subpar flooring put up obstacles and gave the disabled a bad feeling in building A. contrary to buildings B and C being clearly identifiable for all users, as shown in Fig. 5.

Curb ramps: There is no curb ramp at building A and just one curb ramp for car walking with a width of 3.00 m at building B reverse to building C shows Crossings and curb ramps be free of obstacles with more than 1.20 m width and landing space more than 1.20 m × 1.20 m and have a detectable warning surface on the sidewalk with a depth of 0.60 m, traffic light systems, and audio signals according to standard codes, as shown in Fig. 5.

Parking spaces: There is no parking in building A and B but providing of parking spaces in building C, providing 1 accessible parking space for every 25 spaces in reverse, the space is

almost 4.00 m for accessible car parking and according to the standard, Car parking spaces must have a minimum width of 2.50 m in addition 1.5 m for accessible space, as shown in Fig. 5.

Figure 5: Entering and existing of the three buildings.

Shelters and seating: According to the standard codes all three buildings Providing with protection shelters, as shown in Fig. 6, including seats to rest and include floor space for wheelchair users directly adjacent to the seat, but just in building C provides benches both back and arm rests to give additional support, as shown in Fig. 7.

Figure 6: Shelters protection of the three buildings.

Figure 7: Seating area of the three buildings.

Handrails on ramps and stairs: According to the code building A doesn`t achieve the UD requirements, there is no handrail on both sides of stairs and ramps and no provision of edge protection, and lack of braille and tactile signage, and just 1.00 m width of the corridor. And building B lack ramps or lifts and 1.00 m width of scaping stairs, providing handrail in some stairs from just one side in comparing with building C providing ramps with width and landing space not less than 1.20 m, handrail on both side with a suitable high of 1.00 m, edge protection on the stairs with suitable landing space 1.20 m, as shown in Fig. 8.

Figure 8: Handrails on ramps and stairs of the buildings.

2. Indoor environment

Reach ranges: Just in building C you can easily reach things according to the standard code the high forward reach must be a maximum of 1.20 m above the floor and the low forward reach must be a minimum of 0.38 m above the floor, as shown in Fig. 9.

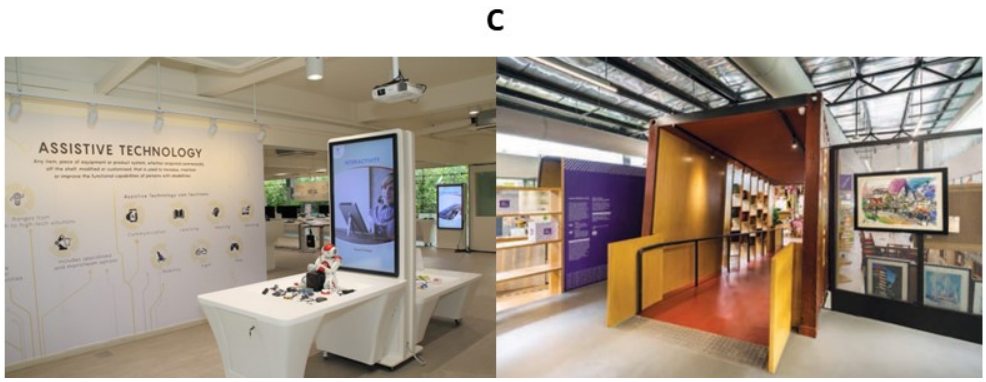

Figure 9: Reach ranges at building C.

Interior accessible routes: it has been achieved just in buildings B and C, according to the code to allow a wheelchair user to comfortably pass a pedestrian should be a minimum of 1.50 m wide.

Wayfinding and signage: Building A doesn`t achieve the UD requirements, building B providing with signage without brail but in building C, according to the standard code Sentence case characters be used as most people recognize a word by its shape when written in a sentence case capital first letter, providing raised signage text, providing braille for wall mounted signs, between 1.20 m and 1.50 m above. the floor, measured to the baseline of the braille cells, large signage pictograms be at least 150 mm tall.

Accessible toilets: The restroom didn't fully implement universal design principles according to the standard, The minimum area of a wheelchair-accessible toilet compartment must be 1.50 m and a minimum of 1.40 m in depth, Need providing with equipped with an alarm system, the door must open outwards. A horizontal grab bar with a minimum length of 1.07 m must be located a maximum of 0.30 m from the rear wall and extend a minimum of 1,370 mm from it. The length of a vertical grab bar must be a minimum of 0.45 m, The bottom of the vertical grab bar must be located at a minimum of 0.99 m and a maximum of 1.04 m above the floor. The fixed rear-wall grab bar must have a minimum length of 0.90 m, located a maximum of 0.17 m from the sidewall, and extend a minimum of 1.07 m from the sidewall, The washbasin or sink must be a maximum of 0.86 m above the floor, shower dimensions of 0.90 m wide, 0.90 m deep, there must have an entry at least 1,500 mm wide, as shown in Fig. 10.

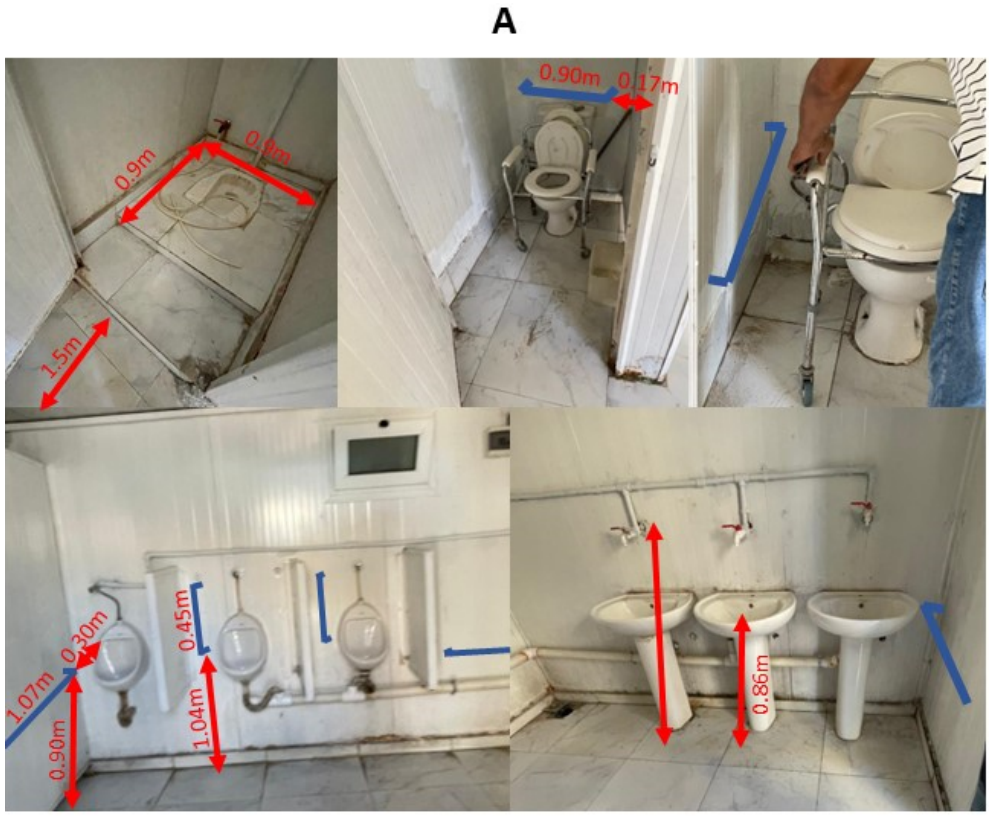

Figure 10: Accessible toilet suggestions at building A.

4.2.4 Discussion and recommendations

Here are some ideas for ensuring that people with disabilities can access, enjoy, and safely use the beach: Utilizing pavement that is climatically resistant will improve the quality of walk floors and roadway paving.

4.2.5 Conclusion

Both sustainability and universal design are crucial strategies for achieving a balance amongst individuals because there can be no social justice without any form of sustainability. The designer would be assisted by the integrated approach in creating buildings that are both universal and sustainable. While universal design concentrates on people, sustainable design is primarily focused on the environment. Universal Design can be seen as a key element for social sustainability in addition to fostering involvement and social engagement within a liveable community. Because it affects human behaviour and quality of life in so many different ways, the social component of sustainability should be highlighted in the general conversation about sustainability. In order to assist designers and prevent time and money waste, as well as to suggest a new future guideline with codes for mental disabilities, the current study describes the construction of an evaluation framework that may be used in the early stages of design when evaluating the performance of buildings using a rating system. Universities should teach universal design to raise early awareness of the need to make current built settings more accessible in order to provide a holistic socially sustainable environment for the benefit of future generations. Additionally, it is crucial to apply smart planning techniques while building homes to prevent unsustainable home modifications that result in pollution, the use of dangerous construction tools and materials, and the improper removal of waste.

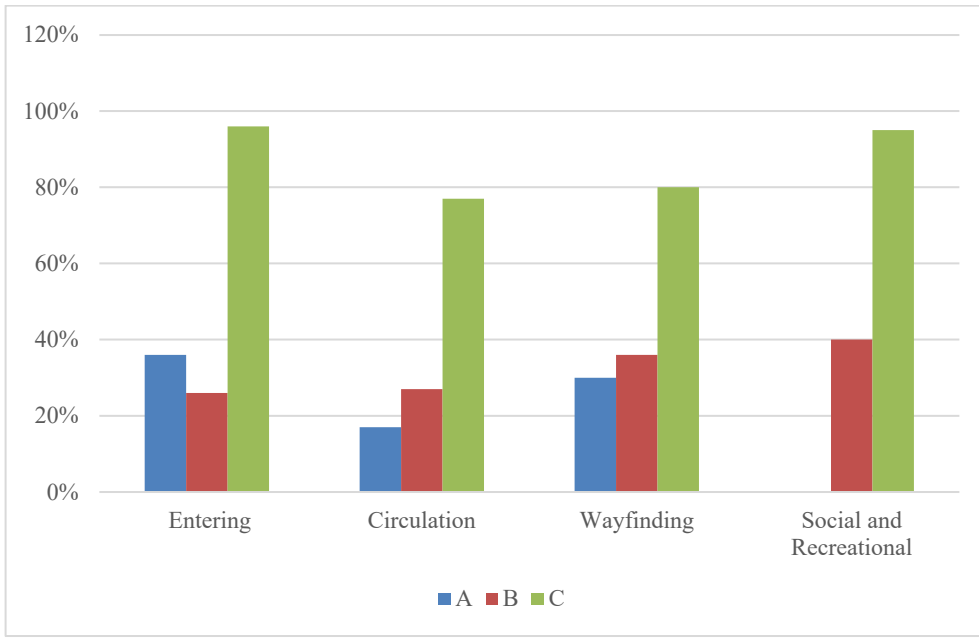

Figure 11: The score of achieving UD for each element in the three buildings.

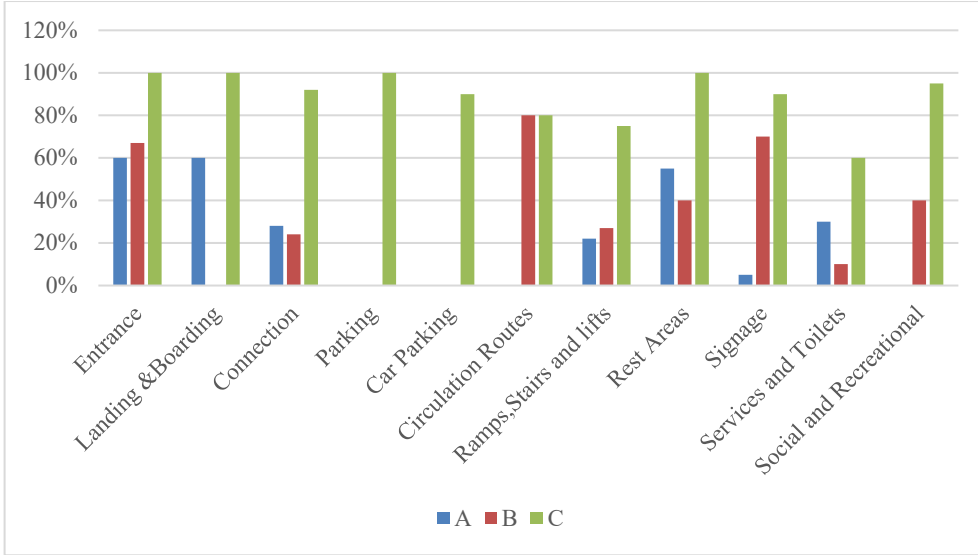

Figure 12: Percentage of achieving UD for the detailed items.

REFERENCES

[1] Central Agency for Mobilization and Statistics, *Statistical Yearbook*: *Alexandria*, p. 112, 2021.

[2] El Kony, H. & El Kony, G., The vernacular affiliation between concepts of social justice and its impacts on design-related agendas. *Assiut University*, **37**(5), p. 1239, 2009.

[3] Esfandfard, E., Wahab, M.H. & Amat, R.B.C., Is Tehran's public spaces disability friendly? *Proceedings of the 1st International Conference on Urban Design and Planning*, p. 2, 2020.

[4] Edirisinghe, J., Making an accessible city: Consideration of universal design principles in city planning. *University of Sri Jayewardenepura,* pp. 4–6.

[5] Arora, V., Planet crust. What is the Definition of Smart City? *Corteza*, **6**(2), 2021. https://www.planetcrust.com/what-is-the-definition-of-a-smart-city?utm_campaign=blog.

[6] Rey Manueco, B., Map and navigation: What is a sustainable city? https://meep.app/blog/what-is-a-sustainable-city/. Accessed on: 21 Apr. 2022.

[7] Mega Risdiana, D. & Dwi Susanto, T., The safe city: Conceptual model development: A systematic literature review. *The 5th Information Systems International Conference*, *Procedia Computer Science*, **161**, pp. 291–299, 2019.

[8] The Interaction Design Foundation, Accessibility. https://www.interaction-design.org/literature/topics/accessibility.

[9] United Nations Human Rights Office of the High Commissioner, Policy Guidelines for Inclusive Sustainable Development Goals; Sustainable Cities and Communities. www.policy-guideline-sustainable-cities.pdf.

[10] Hishamuddin Zakaria, M., Sanusi Hassan, A., Azhar Ku Hassan, K. & Ismail, M., Architecture for healing: phenomenology of spatial awareness to evoke healing environment in urban realm. *International Transaction Journal of Engineering*, 2018.

SECTION 6
ENERGY CONVERSION AND GENERATION

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DISPOSAL OF PYROLYSIS RESIDUE BY INCINERATION

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ABSTRACT

In order to exploit all the energy potential that lies in the processing of waste material or biomass, there is a public pressure to recover as much of the material as possible before the landfill process takes place. One widespread method is the gasification process, which can generate a potentially energy-harvestable gas or liquid based on the set gasification conditions. The only waste material is the solid residue (char), which often contains large amounts of carbon (up to 84%), making it suitable for further use. One way of using char is to burn it in an experimental fluidisation unit, which is suitable for burning up to 3 kg·h of char and generating an equivalent gas (flue gas). The fully controllable fluidised bed combustion unit has a diameter of 140 mm and a height of up to 350 cm, and the fluidised bed consists of ST 54 glass sand with a mean grain size of 0.22 mm. This combustion process reduces the volume of the original material by up to 95%. The gas generated by the combustion process represents a potential for use in heat exchangers for heating feed water, in drying plants or cement plants. The quantitative and qualitative evaluation of the resulting thermal process products is described in this paper, as is the pyrolysis and combustion unit. The average low heating value (LHV) for pyrolysis char is 20.3 MJ kg^{-1}, which represents a great potential in terms of its energy recovery. The reduction in volume of the original sample is 52.9–91.6%, where the heat output of the flue gas is 5.54–15.27 MJ kg^{-1}.

Keywords: pyrolysis, char, incineration.

1 INTRODUCTION

Today, electricity consumption is growing and in 2018 was 23.4 trillion kilowatt hours compared to 2000 when global consumption was 13.3 trillion kilowatt hours, an increase of 76% [1]. Hand in hand with this fact, waste production is also increasing, with the current production of two billion tons of waste per year [2]. In this sense, great emphasis is placed on the recovery of waste, primarily for reuse, recycling or energy recovery. Pyrolysis is one of the ways to use waste or biomass for energy purposes [3].

Pyrolysis is the thermochemical decomposition of organic matter into noncondensable gases, condensable liquids and solid residual coproduct (char) [4]. This treatment is characterised by exposing the material to high temperatures in the absence of airborne oxygen. During the process, the feedstock undergoes physical and chemical degradation into different molecules. It is an endothermic process that is achieved by the high energy content of the common materials [5]. This study focuses on the pyrolysis process of six feedstocks, namely: solid recovered fuel (SRF), digestate, straw, polyethylene, hay pellets and tires.

The solid residual coproduct called char is mainly perceived as a by-product of the pyrolysis process, but it also carries a relatively large amount of energy that could be used [6]. This study works with the concept of combustion of char in an experimental fluidized bed unit, which produces a gas (flue gas) that is further suitable for energy recovery in thermal or electrical power generation. This experimental fluidized bed combustion unit is characterized by its versatility, therefore a wide range of materials can be burned in it as the paper shows [7].

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The resulting combustion process is monitored by pressure sensors, flow meters and thermocouples located along the entire length of the combustion unit. For quantitative and qualitative evaluation of the composition of the exhaust gas, an analyser based on the FTIR atmosFIRt by protea principle is applied. This analyser is capable of detecting CO_2, CO, H_2O, NO, NO_2, N_2O, SO_2, NH_3, HCl, HF, CH_4, C_2H_6 and O_2 [8].

The novelty of this study lies in the determination of the mass loss of char due to its combustion in an experimental fluidization unit to form an energy gas. The percentage loss of char, the flue gas production due to the combustion of 1 kg of char in six different feedstocks and the energy potential of the flue gas in terms of use in feedwater preheating, evaporator or steam superheater are described [9].

2 EXPERIMENTAL WORK

2.1 Pyrolysis unit

The experimental process was carried out on a laboratory pyrolysis unit (Fig. 1). It is a small batch reactor with the possibility of reaching a maximum temperature of 900°C. The advantage of the unit is its smaller scale, which allows flexible operations and to perform more tests in less time. The packed bed reactor can hold fuel in the range of 100–1000 g depending on the granulometry and density of the fuel. The laboratory unit can be divided into multiple process units such as reactor, product cooler, pyrolysis gas cleaning with subsequent analysis. For ease of handling, the fuel is loaded in a steel liner. The reactor is composed of two parts – the vessel body itself and the lid. Two electrical elements are located on the outside of the vessel. The first is wound on the cylindrical part of the reactor, under which a thermocouple is placed to monitor the temperature of the reactor shell. The second element is placed on the bottom of the reactor. The individual heating elements can be independently controlled to adjust the temperature in the reactor. A pipeline for the pyrolysis products and the inerting gas supply is located at the top of the reactor.

All configuration and process settings are done via a PLC control unit that is connected to a computer. In the user interface of the computer, it is possible to observe the data in real time, while at the same time the data is stored on disk.

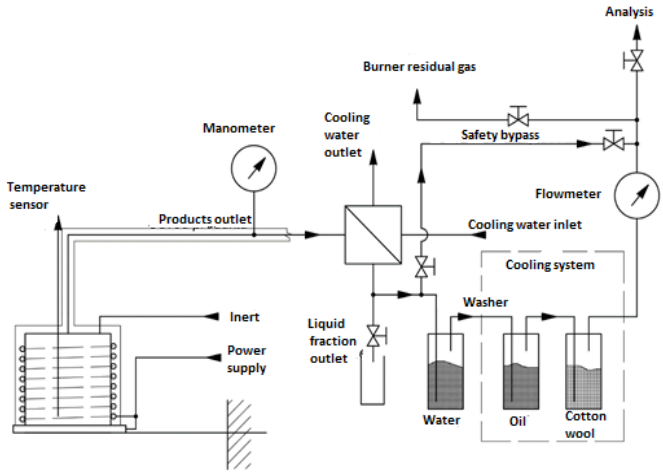

Figure 1: Scheme of pyrolysis experimental setup [10].

2.2 Incineration experimental setup

The experimental combustion unit (Fig. 2) is situated as a fluidized bed reactor with a stationary fluidized bed. Fuel input is provided by two screw conveyors with a conveying capacity of up to 3 kg·h^{-1}. The controllability of the conveyors is in the range of 0–100%. Combustion air conveyance is provided by a blower with a capacity of 57 m^3·h^{-1}, which is also adjustable between 0–100%. The air blower is followed by a combustion air preheater which can operate in the range 0–500°C. To monitor the combustion air flow rate, an air flow meter is located behind the air preheater. Ensuring the required temperature for fuel ignition is achieved by resistance heaters with a total power input of 8.8 kW. The unit is also equipped with a secondary air source that can be used for CO afterburning or primary/secondary air splitting. The underpressure in the whole system is created by a smoke fan with an output of 300 m^3·h^{-1}.

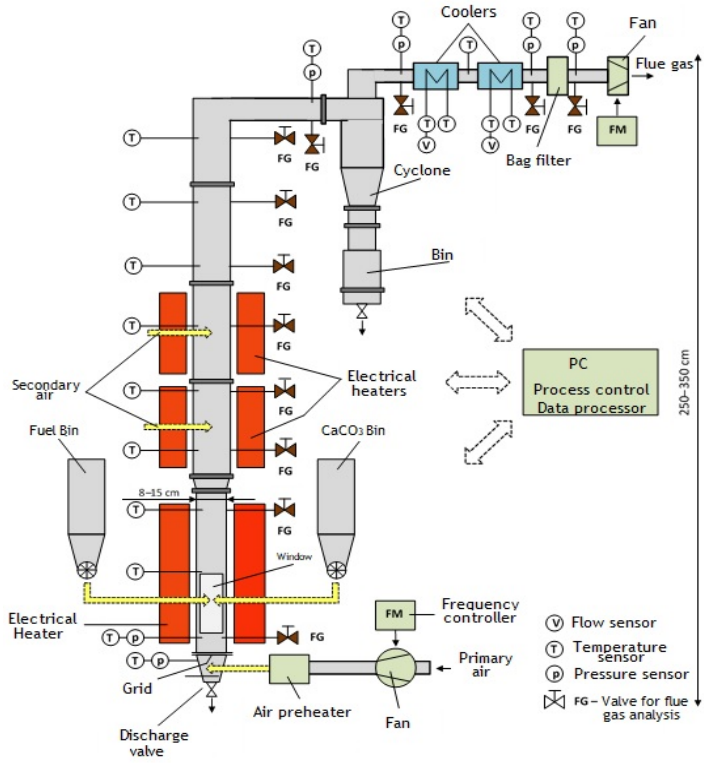

Figure 2: Scheme of experimental incineration unit [7].

The fluidized bed is made up of ST 54 glass sand with an average grain size of 0.22 mm. The base height of the fluidised bed in steady state is 100–140 mm depending on the type of fuel and mainly the ash content. As it is a stationary fluidised bed without continuous drainage, it must be taken into account that during combustion the ash produced is deposited in the fluidised bed, whereby the bed is gradually degraded. For this reason, the operating time of the unit is a maximum of five operating hours, considering the ash content of the fuel.

2.3 Combustion equation

To determine the total heat output of the flue gas, it is necessary to perform a stoichiometric calculation of perfect combustion and determine the required volume of combustion air [11]. Minimum dry air volume $V_{air,min}$ for the ideal combustion of 1 kg of fuel is based on the equation:

$$V_{air,min} = \frac{100}{21}\left(22.39 \cdot \left(\frac{C^r}{12.01} + \frac{H^r}{4.032} + \frac{S^r}{32.06} - \frac{O^r}{32}\right)\right), \quad (\mathrm{m^3_N \cdot kg^{-1}}) \quad (1)$$

where C^r, H^r, S^r, O^r (–) represent, respectively, the relative concentrations of carbon, hydrogen, sulphur and oxygen in the raw sample.

The real amount of combustion air $V_{air,r}$ is based on the equation:

$$V_{air,r} = V_{air,min} \cdot \lambda \cdot \nu, \quad (\mathrm{m^3_N \cdot kg^{-1}}) \quad (2)$$

where λ is the equivalence ratio and ν the proportional increase in air volume due to moisture content.

The amount of water in the flue gas is determined from the equation:

$$V_{H2O} = \frac{44.8}{4.032} H^r + \frac{22{,}4}{18.016} w^r + (\nu - 1) V_{air,min}, \quad (\mathrm{m^3_N \cdot kg^{-1}}) \quad (3)$$

where w^r represents the relative moisture content.

An essential parameter for the assessment of fuel quality is the determination of low heating value (LHV) by Dulonga [12]:

$$LHV^r = 33.91C^r + 121.42H^r + 10.47S^r - 15.18O^r - 2.45w^r. \quad (\mathrm{MJ \cdot kg^{-1}}) \quad (4)$$

For flue gas heat utilisation purposes, the specific enthalpy of the flue gas needs to be determined depending on its temperature and composition. The specific enthalpy of the flue gas can be expressed as the sum of the enthalpies of the gas components. It is necessary to define the specific enthalpy of the stoichiometric flue gas $h_{fg,min,s}$ for $\lambda = 1$, the enthalpy of the minimum amount of air $h_{air,min}$, flue gas enthalpy $h_{fg,r}$ of a given temperature when burning 1 kg of fuel with excess air α and heat output of flue gases Q_{fg}:

$$\begin{aligned} h_{fg,min,s} = {} & V_{CO2} \cdot h^t_{CO2} + V_{SO2} \cdot h^t_{SO2} + V_{CO} \cdot h^t_{CO} + V_{NOx} \cdot h^t_{NOx} + V_{N2} \\ & \cdot h^t_{N2} + V_{CH4} \cdot h^t_{CH4} + V_{NH3} \cdot h^t_{NH3} + V_{HCl} \cdot h^t_{HCl} + V_{H2O} \\ & \cdot h^t_{H2O} + a_{fa} \cdot A^r \cdot h^t_{fa} \end{aligned} \quad (\mathrm{MJ \cdot m^{-3}_N}) \quad (5)$$

$$h_{air,min} = V_{air,min} \cdot h^t_{air} + (\nu - 1) V_{air,min} \cdot h^t_{H2O}, \quad (\mathrm{MJ \cdot m^{-3}_N}) \quad (6)$$

$$h_{fg,r} = h_{fg,min,S} + (\lambda - 1) \cdot h_{air,min}, \quad (\mathrm{MJ \cdot m^{-3}_N}) \quad (7)$$

$$Q_{fg} = V_{spal} \cdot h_{fg,S}, \quad (\mathrm{MJ \cdot kg^{-1}}) \quad (8)$$

where V_{CO2}, V_{SO2}, V_{CO}, V_{NOx}, V_{H2O}, V_{N2}, V_{CH4}, V_{NH3}, V_{HCl} represent the relative volume fractions in 1 m^{-3}_N of the individual components in the flue gas, h^t_{CO2}, h^t_{SO2}, h^t_{CO}, h^t_{NOx}, h^t_{H2O}, h^t_{N2}, h^t_{CH4}, h^t_{NH3}, h^t_{HCl} (kJ m^{-3}) represent the enthalpies of the individual components as a function of temperature, a_{fa} represents the relative fly ash drift, A^r is the relative ash content of the fuel, h^t_{fa} (kJ m^{-3}) is the enthalpy of fly ash and V_{spal} ($m^3 \cdot kg^{-1}$) is the amount of flue gas generated by incineration of 1 kg of fuel.

3 RESULTS AND DISCUSSION

3.1 Pyrolysis process

As these are quite diverse materials, each fuel needs to be treated individually. For example, the carbon content of the raw material ranged from 38.6% to 78.8% and the hydrogen content from 2.43% to 5.59%. The ash content was also very variable, ranging from 34.59% for polyethylene to only 6% for tyres.

Another important aspect is the residence time of the fuel in the reactor, with the longest residence time for straw and specifically 190 minutes and the shortest, 90 minutes, for polyethylene. The long residence time for straw was due to the lower process temperature of 350°C compared to the others, which ranged from 430°C to 600°C, which agrees with other studies [13], [14]. The weight of the batch was always selected individually depending on the specific volume of the material so that the reactor was suitably filled.

The output yields of the different fractions also varied. The highest proportion of char was in SRF, up to 77 wt.%, while the lowest proportion of solid residue was in polyethylene, 16 wt.%. As for the gas fraction, the yields ranged from 15 to 30 wt.% except for SRF, which was the outlier with a yield of only 3%. The liquid fraction was 14 to 61 wt.% [15], [16].

Elemental analysis and determination of water and ash content were applied to define the composition of the char as a fuel for further combustion in the fluidised bed experimental unit. The resulting values are given in Table 1.

Table 1: Elemental composition of the solid residue (char) + water and ash.

Feedstock	C	H	S	N	O	Water	Ash
				(wt.%)			
SRF	40.8	5.34	0.31	0.87	12.5	4.0	36.2
Digestate	45.2	2.13	0.40	2.61	8.1	14.3	27.2
Hay pellets	43.9	10.18	0.19	1.88	7.8	4.5	31.6
Straw	38.1	4.59	0.21	0.16	9.1	2.2	45.6
Polyethylene	39.9	1.59	0.14	0.16	2.5	3.2	52.2
Tyres	82.3	1.16	2.84	0.45	2.5	0.8	10.1
Uncertainty ± (%)	0.5	2	3	3	–	2	1
Standard	EN ISO 16948	EN ISO 16948	EN ISO 16994	EN ISO 16948	EN ISO 16993	EN ISO 181234-2	EN ISO 18122

3.2 Char incineration

Fig. 3 shows the temperatures at the combustion point, in the middle of the reactor and at the reactor outlet, with thermocouples placed at 100 mm, 1100 mm and 1800 mm and the grate. The results show that the combustion temperature varies considerably due to the calorific value of the fuel and its composition. The highest temperature was for tyres, namely 1078°C, followed by hay pellets with 1042°C. This temperature was at the edge of the carrying

capacity, in the sense of melting the reactor. The combustion temperature factor affects the final flue gas temperature at the reactor outlet, with tyres at 482°C and hay pellets at 450°C. In contrast, the lowest temperatures were 589°C for polyethylene at combustion and 323°C at the outlet. The stabilisation process was complicated due to the different calorific value of the material, its size and density. The flue gas temperature had a large effect on the heat outputs [17], which is clearly seen in the results. Temperature measurements were carried out for 30 minutes for all six samples, each time from the time of stabilisation of the combustion process.

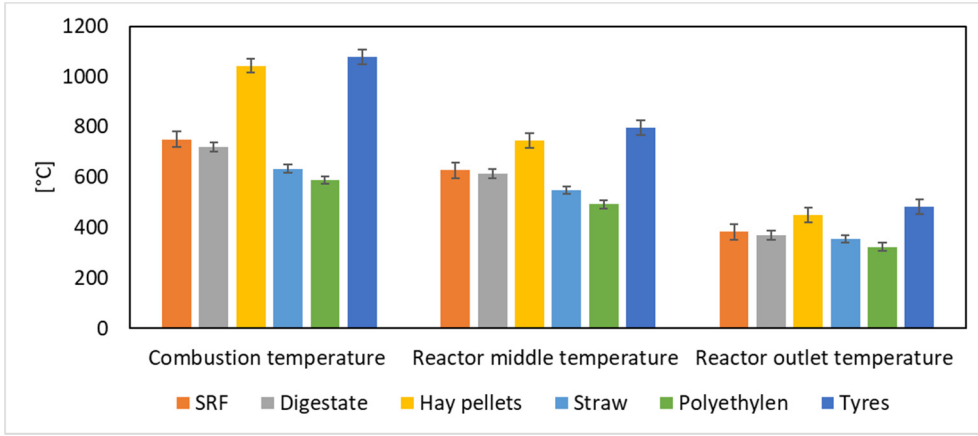

Figure 3: Temperature course in the reactor.

Table 2 shows the average concentrations of the measured flue gas components as average values over a period of 30 minutes. The slightly elevated CO concentration for hay pellets is due to the size of the pellets, which slow down the combustion process by accumulating material in the reactor hearth. The higher carbon and hydrogen content contributed to the slightly increased methane concentration in the flue gas primarily for tyres, SRF and hay pellets. The oxygen concentration range was in the range of 7.1–8.2 vol.%, resulting in a relatively stable combustion process. The high sulphur content of the fuel was reflected in the SO_2 concentration for tyres, where its concentration exceeded the others by almost a factor of two. All measured concentrations (except H_2O and O_2) were converted to normal conditions i.e. 101325 Pa, 0°C, dry condition and reference oxygen content of 6 vol.%.

Table 2: Average composition of the individual flue gas components.

Fuel	H_2O	CO_2	O_2	CO	SO_2	NO	NH_3	HCl	CH_4
	(vol. %)			($mg \cdot m^{-3}$)					
SRF	9.3	5.1	8.2	65.1	1,291.8	421.5	0.8	15.6	29.5
Digestate	8.7	5.6	8.1	57.8	1,378.9	613.8	1.0	8.4	17.5
Hay pellets	8.2	5.3	7.3	133.5	1,233.3	570.5	0.5	58.7	28.3
Straw	10.2	4.3	8.1	77.2	1,401.7	391.5	1.1	21.3	1.2
Polyethylene	7.6	3.9	7.9	88.4	1,178.5	386.1	1.3	14.7	4.3
Tyres	10.3	5.8	7.1	75.1	1,908.6	400.7	1.7	1.3	35.9

Depending on the combustion equation, the average calorific value of the fuels was determined, which depended on the elemental composition. Results from Table 3 show that the pneumatic sample has the highest LHV, namely 29.21 MJ·kg^{-1} which corresponds to a high coal content of 82.3 wt.% in the sample. Next in line are hay pellets, where the high LHV is primarily due to the high hydrogen content of the sample, 10.18 wt.%. The average LHV was 20.3 MJ·kg^{-1}. The mass reduction of the original sample was an important parameter in this study. The mass loss Δm was determined based on the balance of the ash material to the amount of ash deposited in the fluidized bed plus the amount of fly ash. It could be shown that the highest mass loss was 91.6% for the tyres sample, which is based on the relatively low ash content of the sample. The lowest mass loss was for the polyethylene sample, namely 52.9%, due to the low LHV (15.02 MJ·kg^{-1}) and the high ash content of the sample (52.2 wt.%). For the calculation of the specific enthalpy $h_{fg,r,}$ the values from the Engineering Equation Solver (EES) by F-Chart software were used depending on the reactor outlet temperature. The average value of $h_{fg,r}$ was 1.1 MJ·m$^{-3}_{N}$. Depending on the flue gas volume V_{spal} and specific enthalpy $h_{fg,r}$, the heat output Q_{fg} of each fuel was determined. The results showed that the best fuel in terms of heat output was the tyres sample, for which Q_{fg} was 15.27 MJ·kg^{-1}. Another relatively high heat output was the hay pellets sample with 12.21 MJ·kg^{-1}. The remaining samples were in the range of 5.54–8.00 MJ·kg^{-1}, and it is up for discussion whether such heat output is sufficient to be further used in heat exchangers.

Table 3: Average density ρ, LHV and particle size D of fuel. Flue gases volume V_{fg}, mass loss Δm, flue gases specific enthalpy $h_{fg,r}$ and heat output Q_{fg}.

Fuel	ρ (kg·m^{-3})	LHV (MJ·kg^{-1})	D (mm)	V_{fg} (m^3·kg^{-1})	Δm (%)	$h_{fg,r}$ (MJ·m$^{-3}_{N}$)	Q_{fg} (MJ·kg^{-1})
SRF	321.4	18.36	0.8	7.25	65.1	1.103	8.00
Digestate	286.4	16.38	1.4	6.73	74.2	1.008	6.78
Hay pellets	231.6	25.98	5.5	10.01	67.6	1.218	12.21
Straw	109.6	17.08	0.7	6.67	58.4	0.98	6.54
Polyethylene	750.0	15.02	0.4	5.86	52.9	0.945	5.54
Tyres	382.4	29.21	2.5	11.31	91.6	1.351	15.27

4 CONCLUSION

The results of the study showed that the pyrolytic residue that would have been condemned to landfill has the potential for reuse. This statement is supported by the result of the heat outputs of the flue gas, which reach values of 15.27 MJ·kg^{-1}, while the average value of heat outputs was 9.06 MJ·kg^{-1}. These values were determined by combusting six different chars in an experimental fluidization unit, which serves as a versatile device for combusting a wide range of materials with different calorific values and different particle sizes. The average LHV was 20.3 MJ·kg^{-1}, which is comparable to black coal mined in Czech mines. Another result that emerged from this study is that the mass loss of material after combustion was up to 91.6%. This study demonstrates that char is a suitable alternative fuel as a possible replacement for conventional fuels with some limitations.

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REFERENCES

[1] Alves, B., Global electricity consumption 1980–2019. Statista, 2021. https://www.statista.com/statistics/280704/world-power-consumption/. Accessed on: 9 Feb. 2022.
[2] Sensoneo, Global Waste Index 2019. https://sensoneo.com/global-waste-index-2019/. Accessed on: 9 Feb. 2022.
[3] Islam, M.K., Khatun, M.S., Arefin, M.A., Islam, M.R. & Hassan, M., Waste to energy: An experimental study of utilizing the agricultural residue, MSW, and e-waste available in Bangladesh for pyrolysis conversion. *Heliyon*, **7**(12), e08530, 2021.
[4] Basu, P., *Biomass Gasification, Pyrolysis and Torrefaction: Practical Design and Theory*, Academic Press, 2018.
[5] Sharuddin, S.D.A., Abnisa, F., Daud, W.M.A.W. & Aroua, M.K., A review on pyrolysis of plastic wastes. *Energy Conversion and Management*, **115**, pp. 308–326, 2016.
[6] Qiao, Y. et al., Analysis of comprehensive utilization of waste tire pyrolysis char by combustion method. *Fuel*, **312**, 122996, 2022.
[7] Jadlovec, M. & Honus, S., Developing of experimental combustion boiler with stationary fluidized bed and multifuels combustion. *MATEC Web of Conferences*, **345**, 2021.
[8] Wang, C., Wu, Y., Liu, Q., Yang, H. & Wang, F., Analysis of the behaviour of pollutant gas emissions during wheat straw/coal cofiring by TG–FTIR. *Fuel Processing Technology*, **92**(5), pp. 1037–1041, 2011.
[9] Trojan, M. & Taler, D., Thermal simulation of superheaters taking into account the processes occurring on the side of the steam and flue gas. *Fuel*, **150**, pp. 75–87, 2015.
[10] Kielar, J., Pavlík, P., Najser, J. & Frantík, J., Návrh možností stanovení optimální doby zdržení v procesu pyrolýzy. *Sborník Přednášek z Konference Energie z Biomasy XVII*, **130**, pp. 51–60, 2016. DOI: 978-80-214-5441-5.
[11] Koppejan, J. & Van Loo, S. (eds), *The Handbook of Biomass Combustion and Co-firing*, Earthscan Association with Int. Inst. Environ. Dev., USA, 2008.
[12] Rédr, M. & Příhoda, M., *Základy tepelné techniky*, SNTL, 1991.
[13] Kloss, S. et al., Characterization of slow pyrolysis biochars: Effects of feedstocks and pyrolysis temperature on biochar properties. *Journal of Environmental Quality*, **41**(4), pp. 990–1000, 2012.
[14] Hossain, M.K., Strezov, V., Chan, K.Y., Ziolkowski, A. & Nelson, P.F., Influence of pyrolysis temperature on production and nutrient properties of wastewater sludge biochar. *Journal of Environmental Management*, **92**(1), pp. 223–228, 2011.
[15] Titiladunayo, I.F., McDonald, A.G. & Fapetu, O.P., Effect of temperature on biochar product yield from selected lignocellulosic biomass in a pyrolysis process. *Waste and Biomass Valorization*, **3**(3), pp. 311–318, 2012.
[16] Kan, T., Strezov, V. & Evans, T.J., Lignocellulosic biomass pyrolysis: A review of product properties and effects of pyrolysis parameters. *Renewable and Sustainable Energy Reviews*, **57**, pp. 1126–1140, 2016.
[17] Wei, H., Huang, S. & Zhang, X., Experimental and simulation study on heat and mass transfer characteristics in direct-contact total heat exchanger for flue gas heat recovery. *Applied Thermal Engineering*, **200**, 117657, 2022.

EVALUATION AND SAFETY ASSESSMENT OF BIOMASS-/WASTE-GENERATED PRODUCER GAS

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ABSTRACT

The production of synthetic gas and alternative liquid fuels, based on renewable and waste source materials, is an emerging topic. With growing energy demand and increasing CO_2 concentration within the atmosphere, caused by excessive fossil fuels combustion, alternative ways of energy utilisation, storage and transformation are intensely being sought and developed. Combining technologies of gasification and Fischer–Tropsch catalytic synthesis of biomass/waste materials can provide not only a possibility to replace fossil fuels extraction, but it can partially solve the issue of growing amounts of unprocessed waste materials. The 200 kW power input technology for gasification of biomass/waste materials with sliding bed, cross/updraft reactor was used to perform experimental measurements of conversion of waste materials into producer gas. This gas, with potential to be used as a source gas for catalytic synthesis was examined from quality and safety points of view. The composition and suitability for its utilisation was evaluated, as well as safety assessment in terms of its explosivity was determined. The latter mentioned was carried out in 1 m^3 spherical explosion vessel to determine pressure rise during the explosion of the producer gas. The results showed interesting differences between measured data and mathematical model, probably caused by the presence of other substances, such as tar compound, solid particles and other pollutants.

Keywords: waste management, solid recovered fuel, gasification, sliding bed reactor, cross/updraft reactor, explosion parameters, explosion pressure 0.02 m^3 explosion vessel.

1 INTRODUCTION

Today it is beyond doubt that our society heads towards fossil-free future. However, this noble errand may be difficult to achieve as alternative approaches are not as spread, reliable, and, in most cases, economically feasible. The energetic sector bears great responsibility in this matter and the implementation of alternative approaches is being very important in short time span. In general, it can be stated that around 84% of energy production comes from fossil resources worldwide, while only around 12% are a consequence of alternative energy sources implementation [1].

In terms of fuel, suitable for wide spectrum of subjects, including energetics and transportation, waste-based material could be a partial solution. Such material literally covers the whole planet, not excluding the uninhabited locations, unfortunately. The waste accumulation is then wrong for two chief reasons: (1) the environment suffers in vicinity of dangerous, decomposing and cumulating substances; and (2) valuable energy content is being wasted [2].

The more or less advanced technologies for sufficient energy from waste transformation exist around the globe, yet even in western world they do not satisfy the actual need, as the waste materials are produced in exceeding rate [2], [3]. For example, several studies that specify biomass-based waste utilization in small combustion applications for household heating were published. Unfortunately, these applications have very limited scope of use and do not solve the overall problem [4], [5]. Moreover, alternative ways of utilisation of this material are, to some extent, ignored. For instance, gasification of so called solid recovered

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fuel (SRF) has a potential to produce CO, H_2 and CH_4 rich producer gas which can be utilised in many ways without causing significant harm to the environment. The application of SRF into waste-to-liquid processes through gasification and Fischer–Tropsch catalytic synthesis can also present an interesting alternative for the future [6].

This study is aimed at evaluation of SRF-based gasification producer gas from energy and safety points of view. The second mentioned is very important consideration which must be done on the most precise level of determination. Safety of fuel materials in terms of their ignition and explosion characteristics must be studied prior handling such materials on industrial or household scale, because, producer gas is dangerous due to its content, combining poisonous and explosive compounds [7]. Several such determinations were made in the past.

Skřínský [8] and Skřínský et al. [9] studied the behaviour of biomass-derived producer gas within 0.2 m^3 spherical explosion vessel at various temperatures and pressures. Also, di Sarli et al. [10] studied similar gas from explosion point of view. He has determined wood chips-derived producer gas explosion pressures. Other works were published on this topic, however, none clearly determines such parameters for the producer gas made out of SRF gasification. Thus, determination of these parameters will be very important in near future, especially while SRF material represents quite a diverse mixture of materials [11], [12].

2 MATERIALS AND METHODS

2.1 SRF material

The very gasification process as well as the character and quality of the producer gas itself are strictly dependent on the input fuel. The character of the fuel can influence the process so much that some of its properties, such as moisture or heating value, may be limiting and can even make the performance impossible. Another important consideration would be the fuel granulometry. This parameter must be in accordance with the design of gasification reactor and its conveyors.

In this study, SRF, produced by OZO Ostrava company, Czech Republic, was used. It represents a mixture of materials collected in a vast location in and around Ostrava city, in form of sorted municipal and industrial non-recyclable wastes. An illustration of its main components is seen in Fig. 1 below, with the dominant compound being non-recyclable plastics and waste wood.

As mentioned above, the granulometry of the fuel must be suitable for the technology. The provided SRF was in the form of soft fluff with high bulk density equal to 109 $kg \cdot m^{-3}$ and grain size of 1–25 mm. From the fuel point of view, a very important factor is its calorific value, or, in other words, lower heating value (LHV). The LHV parameter determines energetic content within chemical bounds of the fuel. This is mostly affected by carbon and partially by hydrogen content. Other components, such as nitrogen, mineral compounds or non-flammable particles diminish the value of LHV, while others, such as sulphur (also enhances LHV), chlorine or mercury can even form environmentally hazardous substances, dangerous to the downstream technology and subsequent producer gas utilisation aggregates as well. Because of the safety reasons during combustion and transport of the fuel, the SRF material was mixed with basic wood pellets (LHV = 17.0 $MJ \cdot kg^{-1}$) in proportion of 3:2.

The results of proximate and ultimate analyses of SRF are summarised in Table 1.

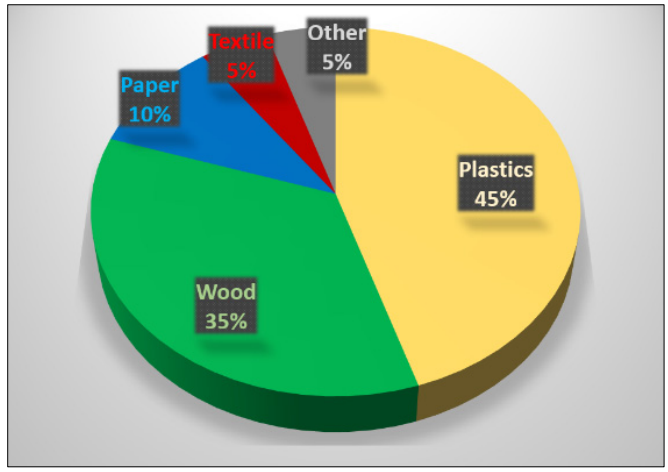

Figure 1: Illustrative composition of SRF.

Table 1: Proximate and ultimate analyses of SRF. All values in raw state.

Parameter	Symbol	Value	Unit
Lower heating value	LHV_f^r	19.1	$MJ \cdot kg^{-1}$
Water	W^r	7.8	% wt.
Ash	A^r	6.2	% wt.
Carbon	C^r	48.8	% wt.
Hydrogen	H^r	6.2	% wt.
Oxygen	O^r	29.4	% wt.
Nitrogen	N^r	1.6	% wt.
Sulphur	S^r	0.1	% wt.
Chlorine	Cl^r	<0.4	% wt.
Mercury	Hg^r	<0.2	$mg \cdot kg^{-1}$

2.2 Gasification process

The process of SRF gasification was performed on a pilot-scale unit of the Energy Research Centre, Centre for Energy and Environmental Technologies, VŠB – Technical University of Ostrava, Ostrava, Czech Republic. This technology is defined by a cross/updraft gasification reactor of 200 kW input power, equipped with sliding bed and circulating grate. Thus, the geometry of the reactor is designed so that fuel is lead from bottom to the grate area and gasification media (air) is brought to it by four tangential nozzles while producer gas is being sucked away in the upper part.

This reactor works in hybrid gasification/combustion regime in order to suffice the necessary temperature for thermochemical reactions (so called autothermal type). A pair of screw conveyors for fuel transportation are designed for materials of 10–30 mm size. The gasification air intake and producer gas outtake are realised by vacuum, caused by a suction fan, situated at the tail of the technology, behind cyclone barrier and moisture/tar condensers.

The sampling of the producer gas is being realised immediately at the reactor outlet, using a screwed sampling probe. The sampling track behind the probe is equipped with impinger

bottles with propane-2-ol, immersed in cold bath environment of 4°C temperature, a suction pump, a flow meter, a gas analyser and an outlet for tedlar sampling bag. The analyser used for molecular composition determination in this study was GAS 3000p, Pollutek Gas Analysis, Belgium. This analyser is capable to determine percental (volume) content of the following gases: CO, CO_2, CH_4, C_nH_m (dual beam infrared detector), H_2 (thermal conductivity detector) and O_2 (electrochemical detector) with 0.01% precision. The technology as well as the sampling track along with sampling methodology used are described in Čespiva et al. [6], [13], [14].

2.3 Explosion experiments

The producer gas explosion experiments were performed in a constant volume, stainless steel, double wall vessel of spherical shape (SN: 497-OZM-15, OZM Research, Czech Republic) adopted for the explosion experiments. This set-up consists of a 0.02 m^3 explosion vessel, heating system, spark generator and data acquisition system, closely described in Skřínský and Ochodek [15].

In order to reduce the number of experimental tests, preliminary thermodynamic and kinetic analyses were performed to predict the fuel–air equivalence ratio resulting in maximum pressure. Knowing the chemical equilibrium composition of the studied chemical system permits the calculation of theoretical, thermodynamic properties for the system. It was assumed that all gases are ideal and that interactions among phases may be neglected within the calculation. The calculation procedure was based on the minimization of free energy and was successfully tested for a similar gas composition in previous studies [16], [17].

The results of adiabatic explosion pressure calculations were used to predict the initial values for experimental producer gas/air measurement and were subsequently put in comparison to measured experimental results as obtained from the explosion vessel.

3 RESULTS AND DISCUSSION

3.1 Gasification process and producer gas quality

The process of gasification was performed in specific conditions in order to adjust the procedure for a unique fuel – SRF. The parameters within the reactor were defined by temperature T = 955.5 K and relative pressure p = −0.2 kPa (p_{atm} = 99 kPa). The consumption of the fuel $\dot{m}_f$ was equal to 40.4 kg·h^{-1} and the gasification air $\dot{V}_a$ equal to 10.4 m^3h^{-1} in ambient temperature of 20°C. Such conditions defined the equivalence ratio λ to be 0.2 with producer gas flow $\dot{V}_g$=73.3 m^3·h^{-1}. All values represent an hour average, during which the gasification process was performed and monitored. Parameters of the gasification process during experimental measurement, including gas composition as monitored at the sampling track, is evident in Table 2.

CGE being determined using:

$$\mathrm{CGE} = \frac{\dot{V}_g \cdot \rho_g \cdot LHV_g}{\dot{m}_f \cdot LHV_f}. \quad \% \qquad (1)$$

The X value represents N_2 in majority. The sampling of the producer gas was done in stabile regime within the reactor and quasi-stable values of the gas components. The gas composition values given represent averages of 30 minutes of sampling. The producer gas was sampled at a rate of 60 l·h^{-1}.

Table 2: Gasification process and producer gas parameters.

Parameter	Symbol	Value	Unit
Temperature	T	950.5	K
Relative pressure	p	−0.2	kPa
Fuel consumption	$\dot{m}_f$	40.4	$kg \cdot h^{-1}$
Air consumption	$\dot{V}_a$	10.4	$m^3 \cdot h^{-1}$
Equivalence ratio	λ	0.2	–
Cold gas efficiency	CGE	30.4	%
Producer gas flow	$\dot{V}_g$	73.3	$m^3 \cdot h^{-1}$
Density	ρ_g	1.3	$kg \cdot m^{-3}$
Thermal capacity	$c_{p,g}$	1.3	$kJ \cdot kg^{-1} \cdot K^{-1}$
Lower heating value	LHV_g	3.2	$MJ \cdot m^{-3}$
Carbon monoxide	CO	10.0	% vol.
Hydrogen	H_2	2.0	% vol.
Methane	CH_4	5.1	% vol.
Carbon dioxide	CO_2	13.6	% vol.
Oxygen	O_2	1.3	% vol.
Other	X	68.0	% vol.

The SRF material was tested in fixed/sliding bed gasification reactors in other studies. Sobolewski et al. [18] examined SRF utilisation in laboratory-scale 60 kW installation. This updraft reactor was able to produce a gas with content of CO = 8.6% vol., H_2 = 5.6% vol. and CH_4 = 2.5% vol. The LHV of this producer gas was equal to 4.3 $MJ \cdot m^{-3}$ [18], [19].

Al-Moftah et al. [20] has studied in his work the life cycle assessment (LCA) of SRF gasification in an updraft unit as alternative replacement for natural gas. The LCA analysis had shown very promising scenarios with positive environmental impact. Čespiva et al. [6] investigated SRF gasification before in similar technology with minor differences. Then, process conditions were defined as temperature 1073 K, pressure 0.1 kPa below atmospheric, fuel flow 9.4 $kg \cdot h^{-1}$ and producer gas flow 40 $m^3 \cdot h^{-1}$. In conclusion, a total of 45.7 kg of alternative liquid fuel was produced out of a ton of SRF material through gasification and synthesis processes over Co catalyst.

3.2 Explosion experiments

A scenario of producer gas pipeline leakage can have fatal impact if mixed with air in vicinity of any energy initiator. The energy within the gas, which can be transformed into explosion, was examined. An experimental explosion vessel was filled with SRF producer gas, as described above, and mixed up with several air concentrations in order to determine maximum explosion pressure. The result of this analysis is depicted in the graph in Fig. 2. As is seen, five explosion tests were enough in order to achieve an explosion curve. The mathematical model in the graph has a high correlation index: $R^2 = 1$. The maximum explosion pressure p_{ex} was determined to be in concentration of air equal to 9.6% vol. and its instantaneous value was 700 kPa.

In terms of explosive content of the producer gas, hydrogen is by far the most crucial parameter. The graph in Fig. 3 below describes the influence of different initial H_2 concentrations within producer gas on the explosion pressure and the pressure rise rate during

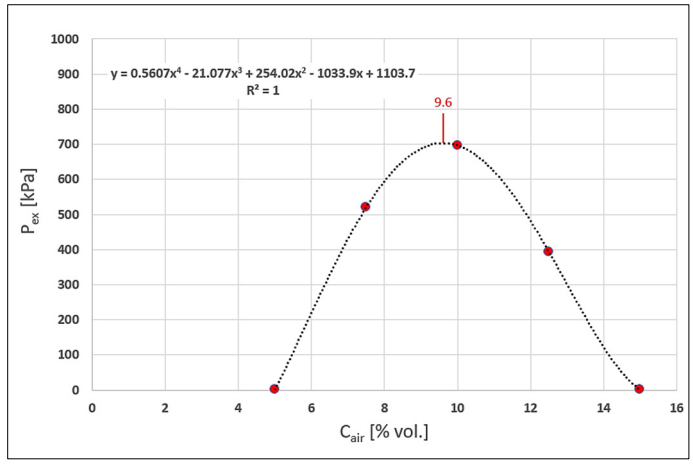

Figure 2: Pressure vs. concentration of air.

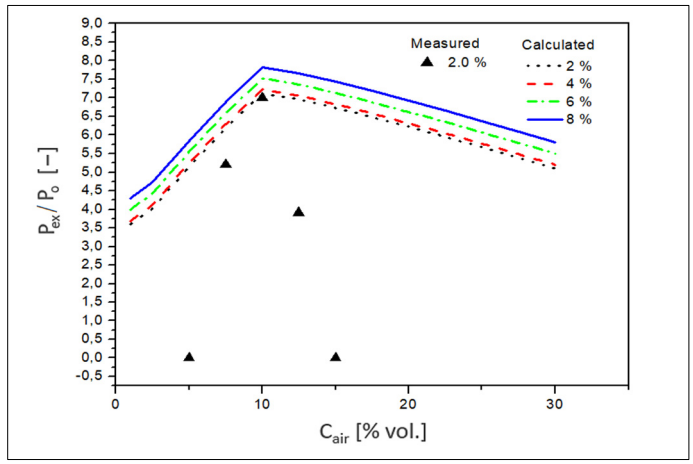

Figure 3: P_{ex}/P_0 vs. concentration for producer gas with 2–8 vol.% of H_2.

the explosion process. This graph followed a mathematical model, as described in Skřínský [8]. The explosion and adiabatic equilibrium pressure are normalized concerning the initial pressure (p_0 = 101 kPa).

The maximum explosion pressure and maximum rate of pressure rise are essential indicators for the evaluation of explosion energy distribution connected to environmental safety. The results of the detailed derivation show certain aspects of H_2 addition effects. A rough correlation with the explosion parameters is also apparent in terms of the pressure–concentration curve slope. The obtained results are crucial for exploring the role of H_2 content in the producer gas mixture.

Skřínský [8] studied the behaviour of biomass derived producer gas within 0.02 m^3 spherical explosion vessel and determined maximal pressure p_{max} = 5.4–7.0 bar and deflagration index K_G = 45–63 bar·m·s^{-1} at various temperatures and pressures. Skřínský et

al. [9] presented a study in which he found maximal explosion pressure p_{ex} = 7.1 ± 0.2 bar and K_G = 170 ± 14 bar·m·s^{-1} for 30% vol. concentration of producer gas in air. This was achieved on the same 0.02 m^3 explosion vessel.

4 CONCLUSION

Alternative sources of energy are very likely to draw society's strong attention. Current anti-fossil trends are about to turn the focus on these alternatives, among which, gasification of waste-based materials will certainly achieve its share in the very near future.

In this experimental programme, producer gas derived from SRF material through the process of gasification was examined from quality and safety points of view. The stable gasification regime in sliding bed, cross/updraft reactor with 950.5 K ambient temperature was able to produce 73.3 m^3·h^{-1} with simultaneous fuel consumption of 40.4 kg·h^{-1}. The energetic compounds of the gas were CO, H_2 and CH_4 in 10:2:5.1 volume rate. The lower heating value of the gas was equal to 3.2 MJ·m^{-3}.

The second part of the experiment included determination of maximal explosion pressure in different mixtures of the producer gas and air. The results showed p_{ex} to be highest at a 9.6% vol concentration of the air. The value of p_{ex} was in this case 700 kPa.

Before the SRF producer gas can be handled with safely in the industrial or local sphere, numerous experiments must be carried out in order to evaluate its potential dangers in the form of poisoning or exploding. This article summarises basic information and provides a basis for further research activities in this field.

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REFERENCES

[1] Ritchie, H., Primary energy consumption by source, World. *Our World in Data*, 4 Feb., 2022.

[2] Kaza, S., Yao, L., Bhada-Tata, P. & van Woerden, F., *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*, International Bank for Reconstruction and Development, 2018.

[3] Wilts, H., Galinski, L., Marin, G., Paleari, S. & Zoboli, R., Assessment of waste incineration capacity and waste shipments in Europe, 2017.

[4] Rýšavý, J. et al., Beech leaves briquettes as fuel for a home combustion unit. *WIT Transactions on Ecology and the Environment*, vol. 246, WIT Press: Southampton and Boston, pp. 75–85, 2020. DOI: 10.2495/EPM200081.

[5] Ryšavý, J. et al., Beech leaves briquettes' and standard briquettes' combustion: Comparison of flue gas composition. *International Journal of Energy Production and Management*, **6**(1), pp. 32–44, 2021. DOI: 10.2495/EQ-V6-N1-32-44.

[6] Čespiva, J., Skřínský, J., Vereš, J., Borovec, K. & Wnukowski, M., Solid-recovered fuel to liquid conversion using fixed bed gasification technology and a Fischer–Tropsch synthesis unit: Case study. *International Journal of Energy Production and Management*, **5**(3), pp. 212–222, 2020. DOI: 10.2495/EQ-V5-N3-212-222.

[7] Eldson, R. & Pal, D., Waste-to-energy plant process safety challenges, 2011.

[8] Skřínský, J., Influence of pressure and temperature on safety characteristics of syngas–air mixture produced by autothermal gasification technology. *Chemical Engineering Transactions*, **65**, pp. 133–138, 2018.
[9] Skřínský, J., Vereš, J., Čespiva, J., Ochodek, T., Borovec, K. & Koloničný, J., Charakterystyka eksplozji gazu syntezowego z procesu zgazowania. *Inżynieria Mineralna*, **2**(1), 2020. DOI: 10.29227/IM-2020-01-66.
[10] di Sarli, V., Cammarota, F. & Salzano, E., Explosion parameters of wood chip-derived syngas in air. *Journal of Loss Prevention in the Process Industries*, **32**, pp. 399–403, 2014. DOI: 10.1016/j.jlp.2014.10.016.
[11] Sarc, R., Kandlbauer, L., Lorber, K.E. & Pomberger, R., Production and characterisation of SRF premium quality from municipal and commercial solid non-hazardous wastes in Austria, Croatia, Slovenia and Slovakia. *Detritus*, **9**, pp. 125–137, 2019. DOI: 10.31025/2611-4135/2019.13871.
[12] Ramos Casado, R. et al., Classification and characterisation of SRF produced from different flows of processed MSW in the Navarra region and its co-combustion performance with olive tree pruning residues. *Waste Management*, **47**, pp. 206–216, 2016. DOI: 10.1016/j.wasman.2015.05.018.
[13] Čespiva, J. et al., Characterization of tars from a novel, pilot scale, biomass gasifier working under low equivalence ratio regime. *Renewable Energy*, **159**, pp. 775–785, 2020. DOI: 10.1016/j.renene.2020.06.042.
[14] Čespiva, J., Skřínský, J. & Vereš, J., Comparison of potential materials for producer gas wer scrubbing in pilot-scale gasification unit. *WIT Transactions on Ecology and the Environment*, vol. 237, WIT Press: Southampton and Boston, pp. 87–96, 2019. DOI: 10.2495/ESUS190081.
[15] Skřínský, J. & Ochodek, T., Explosion characteristics of propanol isomer–air mixtures. *Energies*, **12**(8), p. 1574, 2019. DOI: 10.3390/en12081574.
[16] Skřínský, J., Vereš, J. & Koloničný, J., Explosion characteristics of blast furnace gas. *Inzynieria Mineralna*, **19**(1), pp. 131–136, 2018.
[17] Skřínský, J., Vereš, J., Peer, V., Friedel, P., Trávníčková, J. & Dalecká, A., Explosion parameters of coke oven gas in 1 m^3 explosion chamber. *Chemical Engineering Transactions*, **53**, pp. 7–12, 2016.
[18] Sobolewski, A., Iluk, T. & Szul, M., Gasification of SRF in a GazEla fixed bed reactor. *WIT Transactions on Ecology and the Environment*, vol. 186, WIT Press: Southampton and Boston, pp. 799–807, 2014. DOI: 10.2495/ESUS140711.
[19] Sobolewski, A., Iluk, T. & Szul, M., SRF gasification in GazEla pilot fixed bed gas generator for CHP units. *Journal of Power of Technologies*, **97**(2), pp. 158–162, 2017.
[20] Al-Moftah, A.M.S.H., Marsh, R. & Steer, J., Life cycle assessment of solid recovered fuel gasification in the state of Qatar, *ChemEngineering*, **5**(4), p. 81, 2021. DOI: 10.3390/chemengineering5040081.

COMPOSITE INDICATORS FOR ASSESSING THE CARBON EMISSION REDUCTION ON BIO-ECO-RESILIENCE OF RESIDENTIAL BUILDINGS

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ABSTRACT
In the 21st century, extreme precipitation and temperature are expected due to climate change. This climate change is induced by carbon emissions, in which residential buildings contribute significantly. We propose a kinetic green façade with a double frame. The first frame is an outdoor frame of bio-vegetation, while the second frame is built of green construction materials with isolated glass. This kinetic skin is intended to mitigate extreme temperature and use extreme precipitation. This system integrates three state-of-the-art approaches: biophilic, ecological and resilience to compact climate changes hazards. In this paper, we established bio-eco-resilience composite indicators (BER-CIs) to assess this modification for existing residential building in the New Borg Al-Arab City (NBC), Egypt in five different scenarios. We find that scenario 5 where the highest vegetation footprints in which all the harmful and unhealthy exposure was utilized sustainably, and carbon sequestration is higher than carbon emissions with BER-CIs of 21.64.
Keywords: green façade, carbon emission, carbon sequestration, composite indicator, RIVET, GIS.

1 INTRODUCTION

Greenhouse gas emissions form residential units strengthening the greenhouse effect, causing climate change [1], and the residential development have not yet peaked. Recently, cities embodied 80% Cities of carbon emissions [2] mainly due to residential building energy consumption [3]. In Egypt, carbon emissions are 73% of total greenhouse gas emissions, in which 44% is due to residential building energy consumption [4]. The European Union (EU) targets to reduce gas emission from 55% in 2030 to nearly zero in 2050 to achieve climate neutrality. Moreover, United Nations Sustainable Development Goals (UNSCD) targets to replace traditional energy by clean renewable energy in 2030 [1] by creating buildings with high-energy efficiency and passive design [5], [6].

Since 2013, Rockefeller foundation "100 resilient city" has organized by gathering difference disciplines such as architecture, urban design, civil engineering, and social sciences. These efforts are held to convert 100 cities to resilience cities able to adapt to climate changes and other issues. A resilient city is expected to be able to reduce the impact of the natural disasters and recover quickly [7], [8]. In this context, "Resilience" is defined as the ability to absorb, adapt, and transform after affect to harmful events, stress and shock [9]. Thus, climate resilience requires the reduction of greenhouse emissions [10] and promoting a healthy coherent system [11].

The socio-ecological system can be described as the dynamic of the city to link the society and human wellbeing to ecosystem service [2]. This system is promoting the sense of place [12], and is regenerating the built environment [13] by linking the engineering resilience with nature to adapt the climate changes [14]. Urban ecosystem has positive influence on people and environment [15]. Recent research efforts discussed socio-ecological system and its impact on the society based on improving urban green infrastructure (UGI) are promoting the sense of place and biodiversity conservation. UGI elements are in macro-scale gardens,


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parks, blue footprints, and micro-scale green spaces, green roofs, green/living walls. UGI was suggested to mitigate climate change either socially [16]–[21] or economically [22]–[27]. Additionally green filtration process within micro-scale UGI is described as Natural Base Solution (NBS). In 2021, researchers suggested that adding new technologies to NBS can establish climate change resilient cities through phytoremediation [28], [29].We believe that these new technologies can be bio-inspired (Biophilic) through covering residential units with multi-bio-functional dynamic skin. These multi-bio-functions combine vegetation, renewable energy, and green building materials. This skin consists of subdivision kinetic units, adapting to environmental changes. In this skin, the vegetation collects, absorbs, and filtrates rain, and reduces the urban heat island. Also, we will utilize renewable energy and green building materials to reduce the overall carbon footprint of the residential units. Thus, this Biophilic approach helps creating a resilient city [30] through achieving the following seven qualities: (1) Reflectiveness by ability to make future decisions based on skin kinetic measurements; (2) Resourcefulness by employing available cost-effective green building materials; (3) Robustness by complying with design building codes and regulations, and testing safety periodically; (4) Redundancy by absorbing, transforming and accepting climate changes; (5) Flexibility by modular design to enable easy implementation of any future technology; (6) Inclusive by enhancing ownership and personal vision of the residents, not exclusively the engineers; and (7) Integration by bring together interdisciplinary designs and technologies. Thus, our proposed system integrates of three aforementioned approaches: Biophilic, ecological and resilience approaches.

In our research, we analysis the predictive weather scenarios at the New Borg Al-Arab City (NBC), Egypt. NBC combines coastal and desert land features [31]. This analysis includes the temperature and precipitation. The temperature and precipitation are anticipated to increase at coastal regions [4]. Then we establish bio-eco-resilience composite indicators (BER-CIs) to measure three parameters: (1) energy consumption; (2) carbon emission; and (3) water conversion. We computational simulated BER-CIs by Revit Autodesk plugins (dynamo, green building studio and BIM), Esri-estimation (ArcGIS) and IBMM SPSS statistics. CIs (composite indicators) are performed from combining of specific indicators into a single index that enable the measurement of multi-dimensions [32]. These single indicators can be classified to key indicators and extensive indicators. Key indicators (KIs) are defined as indicators that can be measured and easy to collect. Extensive indicators (EIs) complete the results of the key indicators to achieve detailed indicator [33].

2 BIO-ECO-RESILIENCE COMPOSITE INDICATORS

Our study proposes adapting to climate change by accepting, absorbing, and transforming extreme temperatures and perceptions to reduce the impact of natural disasters. BER-CIs (bio-eco-resilience composite indicators) measure three parameters: (1) energy consumption; (2) carbon sequestration; and (3) water conversion. BER-CIs have three CIs, eight KIs, and 15 EIs, as shown in Table 1.

CIs 1, 2, and 3 focuses on promoting nearly zero energy, carbon, and water, respectively. CIs 1 is established by combining four KIs (from 1 to 4) and seven EIs (from 1 to 7), CIs 2 is established by combining two KIs (5 and 6) and four EIs (from 8 to 11), and CIs 3 is established by combining two KIs (7 and 8) and four EIs (from 12 to 15). In this paper, we solely classify, evaluate and measure CIs 2. Bio-eco-resilience with nearly zero carbon (CIs 2: BER-nearly zero carbon) is defined as the total amount of carbon sequestration from healthy bio-vegetation lying in BER-residential units. The best-case scenario when CIs value increases, indicating reduction of the greenhouse gas emissions to approximately zero.

Table 1: Bio-eco-resilience composite indicators (BER-CIs) classification.

BER-CIs			**Best-case scenario**	**Multi-dimensions**
CIs.1		**BER-nearly zero energy**	**Low value is better**	
KI.1		BER-EC (MJ/m^2/Yr.)	Low value is better	Residential units (shelters) and built environment
	EI.1	EU (MJ/m^2/Yr.)	Low value is better	
	EI.2	REP (MJ/m^2/Yr.)	High value is better	
KI.2		BER-Elec. C (MJ/m^2/Yr.)	Low value is better	
	EI.3	Elec. C (MJ/m^2/Yr.)	Low value is better	
	EI.4	NVEES (MJ/m^2/Yr.)	High value is better	
	EI.5	SEES (MJ/m^2/Yr.)	High value is better	
KI.3		BER-EEI (MJ/m^2/Yr.)	Low value is better	
KI.4		BER-Elec. C Cost ($)	Low value is better	Economy
	EI.6	Elec. C Cost ($)	Low value is better	
	EI.7	NVEES. Cost ($)	High value is better	
CIs.2		**BER-nearly zero carbon**	**High value is better**	
KI.5		BER-CSS (Kg. C/m^2/Yr.)	High value is better	Residential units (shelters) and built environment
	EI.8	EC (Kg. C/m^2/Yr.)	Low value is better	
	EI.9	CS (Kg. C/m^2/Yr.)	High value is better	
KI.6		BER-Vegetation (%)	High value is better	Built environment and economy
	EI.10	VVF (m^2).	High value is better	
	EI.11	HVF (m^2).	High value is better	
CIs.3		**BER-nearly zero water**	**High value is better**	
KI.7		BER-WSI (L/Yr.)	High value is better	Residential units (shelters) and built environment
	EI.12	RRWHS (L/Yr.)	High value is better	
	EI.13	NVWS (L/Yr.)	High value is better	
KI.8		BER-WCS ($)	High value is better	Economy
	EI.14	RRWHCS ($)	High value is better	
	EI.15	NVIWCS ($)	High value is better	

KI 5 (kg. C/m^2/Yr.) is calculated by subtracting EI 9 from EI 8. EI 9 measures carbon sequestration (CS). CS is defined as the total amount of carbon sequestration in BER-units due to vegetation and green building materials. While EI 8 measures embodied carbon (EC). EC is defined as the total amount of carbon embodied during the construction process. KI 6 (%) is calculated by adding EI 10 and EI 11 as a percentage of total residential unit area. EI 10 and EI 11 (m^2) measures vertical (VVF) and horizontal (HVF) vegetation footprint, respectively. We used EC coefficients from the Inventory of Carbon and Energy (ICE) database [34], [35] for EI 8, CS coefficients from Arodudu et al. [36] for EI 9. Then the collected coefficients were applied and simulated into material mass of the BER-residential unit using Revit Autodesk building information modelling (BIM) plugin. Then we employ IBM SPSS software to perform statistical analysis to find CIs 2 value. This statistical analysis

was performed by checking reliability, then defining normalization and estimating weight coefficient of various KIs and EIs. After that the CIs sensitivity and correlation was checked. This quantitative methodology of CIs construction is well-explained in details in Nardo et al. [32].

3 CASE STUDY: A RESIDENTIAL BUILDING AT NBC, EGYPT.

We propose a kinetic skin with a double frame. The first frame is an outdoor frame of bio-vegetation, while the second frame is built of green construction materials with isolated glass. In this section, we will apply five scenarios on a residential building. We generated five scenarios by varying skin normalize curve parameter (NCP) using ladybug dynamo plugin in Autodesk Revit. The proposed skin divided into regular parametric units. Each parametric has a triangle shape with unique dimensions. These dimensions are proportional to the skin surface area. NCP varies from 0.1 to 0.9. The parametric units are fully exposed to sunlight at NCP 0.1. Healthy natural sunlight exposure for residents at NCP $\geq$ 0.5. So, we varied NCP values from 0.1 to 0.5 with 0.1 increment for maximum exposure of the kinetic skin.

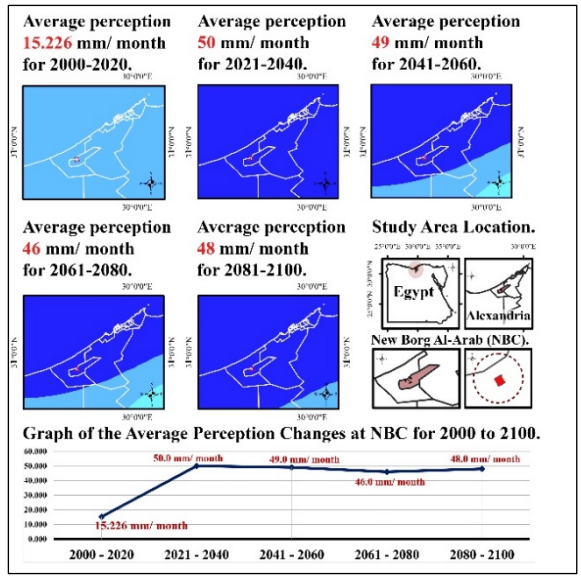
The New Borg Al-Arab City (NBC) is new residential and industrial development city with coastal and desert land features [31]. National aeronautics and space administration (NASA) is predicting NBC to suffer increasing in both perception and temperature due to climate change, each is an exclusive predicament of coastal and desert land as shown in Fig. 1(a) and (b), respectively. We generated Fig. 1 by kriging analysis method using ArcGIS for five periods: 2000 to 2020, 2021to 2040, 2041 to 2060, 2061 to 2080, and 2081 to 2100. NBC has two residential units' prototypes. These prototypes are covered with non-thermally insulated brick walls, non-thermally insulated windows, and non-insulated concrete tile roofs [31]. Thus, these units lack thermal comfort. We selected a 320 m^2 residential unit located in in the centre of the first neighbourhood at a south-east direction latitude of 30°52`30`` north and longitude 29°34`30`` east at NBC. The study area covered an area of approximately 391.97 km^2, of which $\approx$ 45.72 km^2 (11.66%) built-up including $\approx$ 34.34 km^2 (8.76%) residential clusters, and $\approx$ 11.38 km^2 (2.90%) public buildings. There are two residential clusters, each with a different prototype. The first cluster consists of 57 units, each unit is 320 m^2. While the second cluster consists of 23 units, each unit is 700 m^2. This data is analysed by Arc GIS as shown in Fig. 2. We estimated current EC and CS and for the selected 320 m^2 unit to be 102 and 0 Kg. C/m^2/Yr. for EI 8 and 9, respectively. Also, the unit has zero vegetation for KI 6.

We simulated the potential solar estimation for the modified unit with kinetic skin. Then we applied 5 aforementioned scenarios to find CIs 2. The maximum sun exposure occurred on 22 July 2021 at 12:00 pm for 45 minutes in NBC area of study. The simulation process is divided into following phases: solar time preparation, simulation, and testing. Sun exposure footprint is simulated and calculated using ladybug dynamo plugin in Autodesk Revit. Fig. 3 shows that $\approx$ 44% of skin footprint is exposed to the maximum exposure (NCP = 0.1) while only $\approx$ 2% at minimum exposure (NCP $\geq$ 0.9). And $\approx$ 9% can be classified as a healthy natural sunlight exposure for residents (0.6 $\leq$ NCP $\leq$ 0.9).

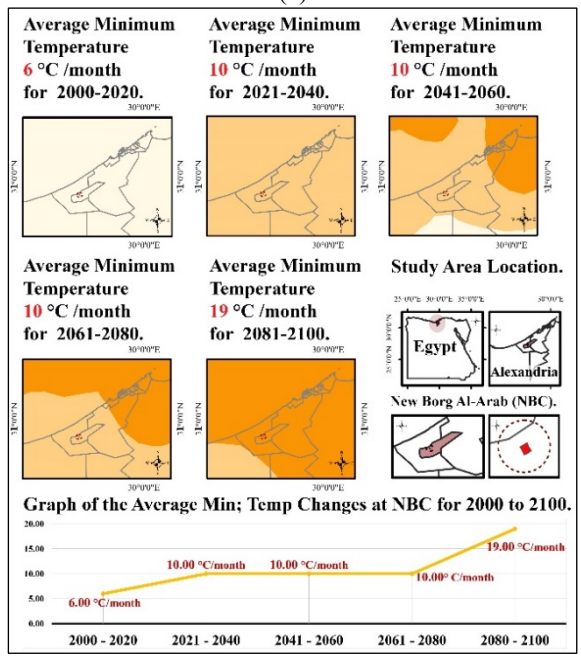
We find potential solar radiation is 44, 57, 71, 82, and 88%, respectively for the 5 scenarios, corresponding to bio-vegetation footprint. Thus, we suggest 56, 43, 29, 18 and 12%, respectively for the kinetic opening for the proposed skin as shown in Fig. 3.

4 RESULT AND DISSUSSION

This section evaluates CIs 2 for 320 m^2 residential unit for 5 scenarios. Table 2 shows the values of KIs and EIs for the 5 scenarios. We evaluate CIs 2 statistically in four stages. First



(a)



(b)

Figure 1: The climate change kriging geo-statistics analysis of Alexandria metropolitan area (includes NBC to the west) from 2000 to 2100. (a) Perception has already risen from 15.226 to 50 mm, starting from 2021 and will stayed relatively stable till 2100, increasing the vulnerability to extreme storms; while (b) Minimum temperature has stayed relatively stable at 10°C from 2021 to 2080, but will rise to 19°C in 2081.

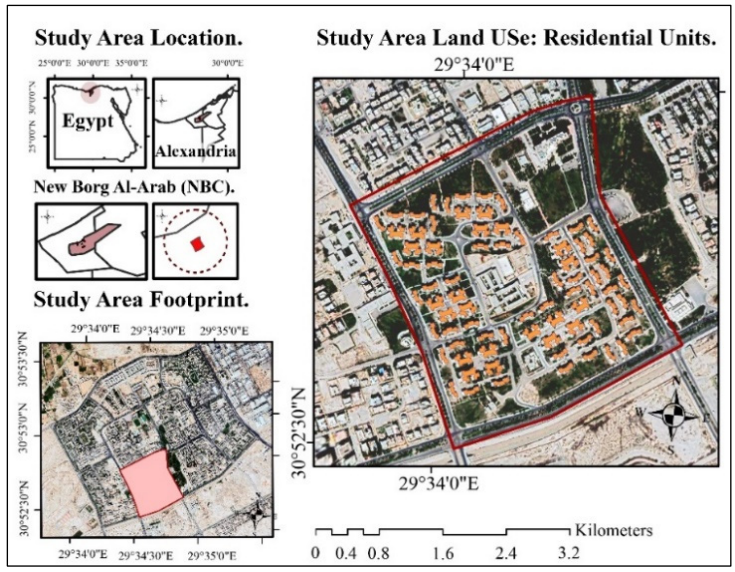


Figure 2: Study area at New Borg Al-Arab City (NBC) location.

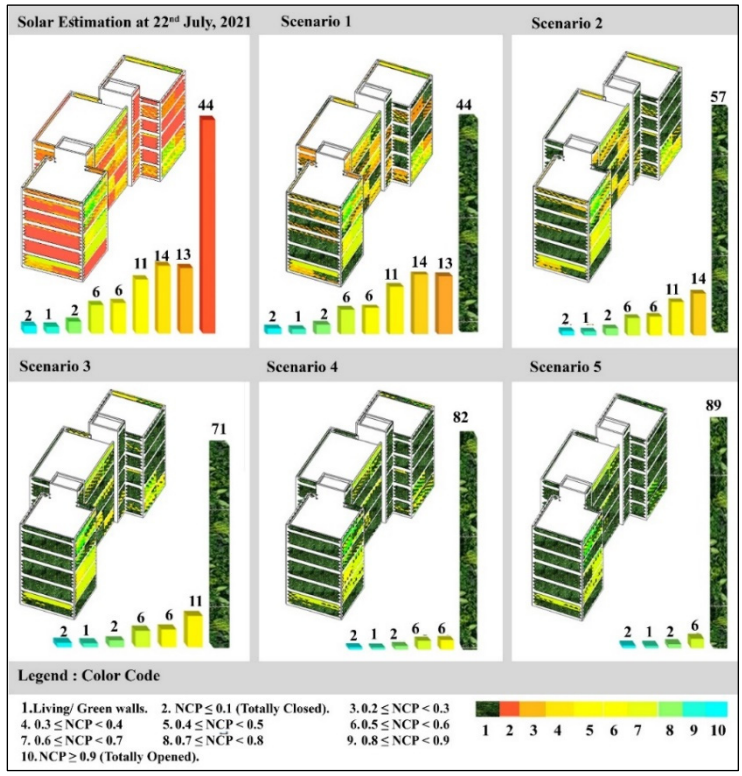


Figure 3: The solar radiation and applying the five scenarios.

stage, we check the reliability statistics between KIs 5, 6, and EIs 8 to 11. An acceptance reliability statistic has been reported: $\alpha \approx 0.796$, and the standard accept value > 0.6 [32]. Then we normalized KI 5 and 6, and EI 8 to 11 using the rescale method with the following equation at the second stage:

$$\frac{In - In_{min}}{In_{max} - In_{min}},$$

where, In is a KI or an EI.

Table 2: The measurement of KIs and EIs at the case study for CIs.

BER-KIs/EIs (Unit area ≈ 320 m²)			**Scenarios**				
			1	**2**	**3**	**4**	**5**
KI.5		BER-CS (Kg. C/m²/Yr.)	2.77	9.6	16.86	22.75	26.06
	EI.8	EC (Kg. C/m²/Yr.)	30.82	27.05	23.32	20.34	18.66
	EI.9	CS (Kg. C/m²/Yr.)	33.59	36.65	40.21	43.09	44.71
KI.6		BER-Vegetation (%)	49.34	61.50	74.03	83.66	88.83
	EI.10	VVF (m²).	1172	1308	1466.4	1594.1	1666.4
	EI.11	HVF (m²).	300	300	300	300	300

The rescale normalization was calculated as 0, 0.0034, 0.0071, 0.10, and 0.117 for KI 5, 0.081, 0.063, 0.046, 0.032, and 0.025 for EI 8, 0.007, 0.017, 0.027, 0.036, and 0.041 for EI 9, 0, 0.1426, 0.2851, 0.4995, and 0.7856. K 10, 0, 0.0009, 0.0019, 0.0027 and 0.0031 for EI 10 respectively for each of the five scenarios. While E 11 is zero for all scenarios. Then we estimated the weight coefficient values for KIs 5, 6, and EIs 8 by principal component analysis to be 13.9, 15.5, 16.017, 15.683, 15.767 and 15.817 at the third stage. In the fourth stage, we aggregated the KIs and EIs by summing of the multiplication of rescale normalized and weight coefficient to find CIs 2. And CIs 2 is 0.14, 2.42, 4.71, 8.12 and 12.64, respectively for each of the five scenarios.

The data identifies the difference occurs for a 320 m² residential unit after converting un-thermal un-insulation walls and windows to bio-vegetation kinetic openings in NBC. Fig. 4 shows that embodied carbon (EC) was reduced from 102 to 30.82, 27.05, 23.32, 20.34, and 18.66 Kg. C/m²/Yr. due to converting the un-thermal insulation brick walls and insulation glass windows into green construction materials, insulation glass, and bio-vegetation walls. Furthermore, carbon sequestration (CS) rises from 0 to 33.59 in scenario 1 then enhanced to

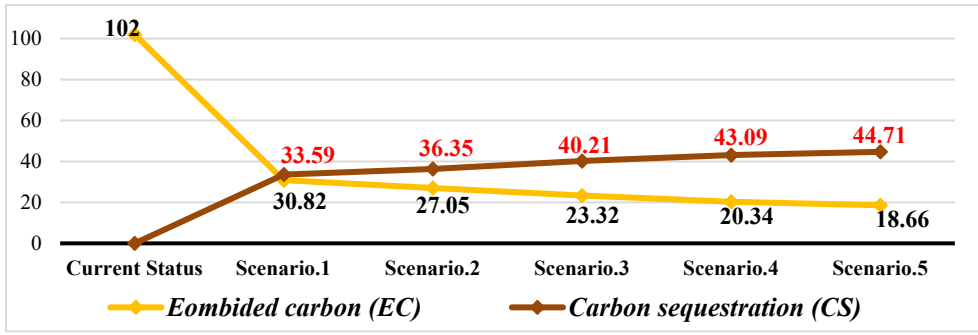


Figure 4: The graph of the impact of five Scenarios at BER-CIs.

be 44.71 in scenario 5 due that vegetation footprints increased from 0 to 49.34 then 88.83, respectively. EC and CS values are shown in Fig. 4.

5 CONCLUSION

Scenario 5 shows the highest vegetation footprints where all the harmful and unhealthy exposure was utilized sustainably. This scenario raises carbon sequestration, decreases the embodied carbon. Thus, this scenario provides the highest BER-CS with nearly zero carbon with CIs of 12.64 compared to 26.06 for the scenario 1. We presented CIs 2 of 3 BER-CSs to assist a proposed kinetic skin to enhance a residential unit at the New Borg Al-Arab city, a city that combined two climate features: the Mediterranean coast and desert land. This research is a part of the efforts to mitigate climate changes in emerging development communities in which extreme temperatures and precipitation is expected.

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REFERENCES

[1] Trincado, E., Bayón, A.S. & Vindel, J.M., The European Union green deal: Clean energy wellbeing opportunities and the risk of the Jevons paradox. *Energies*, **14**(14), pp. 1–23, 2021.

[2] Heymas, A., Breadsell, J., Morrison, G.M., Byrne, J.J. & Eon, C., Ecological urban planning and design: A systematic literature review. *Sustainability*, **11**(13), pp. 1–20, 2019.

[3] Seto, K.C., Churkina, G., Hsu, A., Keller, M., Newman, P.W., Qin, B. & Ramaswami, A., From low- to net-zero carbon cities: The next global agenda. *Annual Review of Environment and Resources*, pp. 377–415, 2021.

[4] BUR, Egypt's first biennial update report to the United Nations framework convention on climate change. Ministry of Environment, Egyptian Environmental Affairs Agency, Cairo, Egypt, 2018.

[5] Cai, L., Feng, X.-P., Yu, J.-Y., Xiang, Q.-C. & Chen, R., Reduction in carbon dioxide emission and energy saving obtained by using a green roof. *Aerosol and Air Quality Research*, **19**(11), pp. 2432–2445, 2019.

[6] Ciriminna, R., Mengeguzzo, F., Pecoraino, M. & Pagliaro, M., Solar green roofs: A unified outlook 20 years on. *Energy Technology*, pp. 1–7, 2019.

[7] Baba, K., Nagata, Y., Kawakubo, S. & Tanaka, M., A frame work and indicators of resilience. *Resilient Policies in Asian Cities: Adaptation to Climate Changes and Natural Disasters*, Springer Nature: Singapore, pp. 3–45, 2020.

[8] Gamaralalage, P.J.D., Maeda, T. & Gilby, S., Enhancing capacities for building climate and disaster-resilient cities in Asia: Case study of Cebu, Philippines and Nonthaburi, Thailand. *Resilient Policies in Asian Cities: Adaptation to Climate Change and Natural Disasters*, Springer Nature: Singapore, pp. 169–194, 2020.

[9] Bush, J. & Doyon, A., Building urban resilience with nature-based solutions: How can urban planning contribute? *Cities*, **9**, 102483, pp. 1–8, 2019.

[10] Dave, M., Varshney, A. & Graham, P., Assessing the climate change adaptability of building. NCCARF (National Climate Change Adaptation Research Facility), 2012.

[11] WHO, *Operational Framework for Building Climate Resilient Health Systems*, World Health Organization Press: Geneva, Switzerland, 2015.

[12] Masterson, V.A., Stedman, R.C., Enquist, J., Tengo, M., Giusti, M., Wahl, D. & Svedin, U., The contribution of sense of place to social-ecological systems research: A review and research agenda. *Ecology and Society*, **22**(1), 2017.
[13] Camrass, K., Urban regenerative thinking and practice: A systematic literature review. *Building Research and Information*, 2021.
[14] Hayes, S., Desha, C., Burke, M., Gibbs, M. & Chester, M., Leveraging socio-ecological resilience theory to build climate resilience in transport infrastructure. *Transport Reviews*, **39**(5), pp. 677–699, 2019.
[15] Threlfall, C.G. & Kendal, D., The distinct ecological and social roles that wild spaces play in urban ecosystems. *Urban Forestry and Urban Greening*, **29**, pp. 348–356, 2018.
[16] Bele, A. & Radeo, U.C., Public perception of biodiversity: A literature review of its role in urban green space. *Journal of Landscape Ecology*, **14**(2), 2021.
[17] Hoyle, H.E., Climate-adapted, Traditional or cottage-garden planting? Public perceptions, values and socio-cultural drivers in a designed garden setting. *Urban Forestry and Urban Greening*, **65**, 2021.
[18] Walsh, E.A., White fragile as an obstacle to anti-racist resilience planning: Opportunities for equity-conscious partnerships. *Journal of Urban Management*, **7**, pp. 181–189, 2018.
[19] Ling, T.Y. & Chiang, Y.C., Well-being, health and urban coherence advancing vertical greening approach towards resilience: A design practice consideration. *Journal of Cleaner Production*, **182**, pp. 187–197, 2018.
[20] Wang, X., Palazzo, D. & Carper, M., Ecological wisdom as an emerging field of scholarly inquiry in urban planning and design. *Landscape and Urban Planning*, **155**, pp. 100–107, 2016.
[21] Krasny, M.E. & Delia, J., Natural area stewardship as part of campus sustainability. *Journal of Cleaner Production*, **106**, pp. 87–96, 2015.
[22] Mitchell, L.M., Houston, L., Hardman, M., Howarth, M.L., Cook, P.A. & Boateng, J.K., Enabling urban social farming: The need for radical green infrastructures in the city. *Cogent Social Sciences*, **7**(1), 2021.
[23] Ogumakinde, O.E., Sher, W. & Egbelakin, T., Circular economy pillars: A semi-systematic review. *Clean Technologies and Environmental Policy*, **23**, pp. 889–914, 2021.
[24] Ling, T.Y., Wu, G.Z. & Lin, J.S., Landscape dimension in the built environment: The spatial operative of an integrated micro agriculture unit. *Journal of Environmental Management*, **226**, pp. 145–155, 2018.
[25] Bowen, K.J. & Lynch, Y., The public health benefits of green infrastructure: The potential of economic framing for enhanced decision-making. *Current Opinion in Environmental Sustainability*, **25**, pp. 90–95, 2017.
[26] Pitman, S.D., Dariles, C.B. & Ely, M.E., Green infrastructure as life support: Urban nature and climate change. *Transactions of the Royal Society of South Australia*, **139**(1), pp. 97–112, 2015.
[27] Symons, J., Jones, R., Young, C. & Rasmussen, B., Assessing the economic value of green infrastructure: Literature review. Victoria University and The Government of Victoria, Melbourne, Australia, 2015.
[28] Lin, B.B. et al., Integrating solutions to adapt cities for climate change. *The Lancet Planetary Health*, **5**(7), 2021.

[29] Ilić, Z.H., Solomun, M.K., Šumatić, N., Ristić, R. & Balaban, Ž.M., The role of plants in water regulation and pollution control. *The Handbook of Environmental Chemistry*, Springer: Berlin, Heidelberg, pp. 1–27, 2021.
[30] Beatley, T., *Handbook of Biophilic City Planning and Design*, Island Press: Washington, DC, 2016.
[31] Rozado, C.A. et al., EcoNBC feasibility study: Transforming New Borg El Arab into an EcoCity, VTT Technology 220, 2015.
[32] Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Hoffman, A. & Giovannini, E., *Handbook on Constructing Composite Indicators: Methodology and User Guide*, OECD Publishing: Paris, p. 162, 2008.
[33] UN-Habitat, Urban indicators guidelines: Monitoring the habitat agenda and the millennium development goals. United Nations Human Settlements Programme, 2004.
[34] Hammond, G. & Jones, C., Embodied energy and carbon in construction materials. *Proceedings of the Institution of Civil Engineers – Energy*, **161**(2), pp. 87–98, 2008.
[35] Hammond, G. & Jones, C., *Embodied Carbon: The Inventory of Carbon and Energy (ICE): A BSRIA Guide*, vol. 164, eds F. Lowrie & P. Tse, University of Bath with BSRIA: Bracknell, UK, p. 136, 2011.
[36] Arodudu, O., Ibrahim, E., Voinov, A. & Doren, I.V., Exploring bioenergy potential of built-up areas based on NEG-EROEI indicators. *Ecological Indicators*, **47**, pp. 67–79, 2014.
[37] Korach, J. & McConnell, A.R., The triadic framework: Integrating nature, communities, and belief systems into the self-concept for sustained conservation action. *Sustainability*, **13**(15), pp. 1–14, 2021.
[38] Keaulana, S., Heede, M.K., Riley, L., Park, M.L.N., Makua, K.L., Vegas, J.K. & Antonio, M., A scoping review of nature, land, and environmental connectedness and relatedness. *International Journal of Environmental Research and Public Health*, **18**(11), pp. 1–35, 2021.
[39] Bele, A. & Radeo, U.C., Public perception of biodiversity: A literature review of its role in urban green space. *Journal of Landscape Ecology*, **14**(2), pp. 1–28, 2021.
[40] Birkeland, J.L., Net positive biophilic urbanism. *Smart and Sustainable Built Environment*, **5**(1), pp. 1–5, 2016.
[41] Feagan, M., Matsler, M. & Meerow, S., Redesigning knowledge systems for urban resilience. *Environmental Science and Policy*, **101**, pp. 358–363, 2019.
[42] Naboni, E., Natanian, J., Brizzi, G., Florio, P., Chokhachian, A., Galanos, T. & Rastogi, P., A digital workflow to quantify regenerative urban design in the context of a changing climate. *Renewable and Sustainable Energy Reviews*, **113**, pp. 1–15, 2019.

RECENT REVIEW OF ENERGY CONSERVATION PLANS AND TARGETS IN THE GULF COOPERATION COUNCIL REGION: BARRIERS AND CHALLENGES

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ABSTRACT

In some parts of the world, such as the Gulf Cooperation Council (GCC) countries, the fast growth of societies supported by rich energy resources, mainly oil and gas, has resulted in expansive urbanization and reliance on increased levels of fossil fuel to completely support new forms of excessively enhanced lifestyles. Despite the small size of their populations, they consume almost as much oil and gas as Indonesia and Japan combined and greater than Africa. Recently, some GCC governments have publicly recognized the unsustainable nature of energy consumption patterns, or at least the tremendous waste they incur. The electricity sector, industry sector and transport sector account for an average of 70%, 50%, and 30% respectively of the total of energy consumption in the countries. This research aims to discuss common and cooperative approaches that could improve energy-efficiency and reduce energy consumption as well as CO_2 emissions in all disciplines. The results confirm the importance of the following factors considering energy conservation: the importance of governance, the need for integration of renewable energy targets and the potential for greater effectiveness through cooperation at the regional level. This research concludes that although all of the GCC countries now have clean energy plans or targets and there are several impressive steps towards conservation but the effectiveness of these clean energy plans is still immature in terms of energy efficiency strategies and reduction of CO_2 emissions. Therefore, it is vital to improve clean energy plans in order to promote energy conservation in the Gulf region.

Keywords: renewable energy, energy efficiency, transport sector, electricity sector, industry sector, Climate change, energy consumption, energy plans and targets, CO_2 emissions, and GCC governance.

1 INTRODUCTION

Discussing the energy policy of the Gulf Cooperation Council (GCC), the GCC was established in 1981 and comprises of the six Arab states of the Persian Gulf (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and UAE). Furthermore, about 40% of the world's proven oil and 23.6% of the world proven gas are carried by GCC countries. As a result, they consume almost 100% of energy that is produced by combustion of oil and gas. Apart from that the GCC have the highest energy consumption in almost every sector – electricity and cogeneration, industry, transport, and non-energy use. CO_2 emissions are soaring along the energy use and contribute to international climate change.

Moreover, the Climate Change Performance Index (CCPI) [1] assessed and compared the climate protection of 57 countries, including the GCC countries, responsible for more than 90% of global energy-related CO_2 emissions. The CCPI ranked Saudi Arabia on the bottom of the list. In 2019, Sweidan [2] stated that the average consumption ecological footprint of the GCC countries (8.9 gha/person) is higher than the world's average consumption ecological footprint. However, the GCC government worked on proposing energy targets and standards throughout integrated energy strategy based on diversification and efficiency targets and moved away from the hydrocarbon sector, aiming energy efficiency.

Consequently, adapting targets such as the share of renewable energy targets and intensity targets could be advantageous to current energy policy and targets of GCC countries and

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have the potential to work and expand beyond national targets level to regional targets level of the GCC countries as well as contribute positively to climate change.

Finally, this paper discusses first the energy consumption and energy use of the GCC countries, second evaluates the current energy targets and strategy and its limitations, and third reviews the previous studies considering the potential of adapting national and regional target level solutions.

2 ECONOMIC AND ENERGY OF THE GULF REGION

Since the discovery of oil in 1930s, the Gulf Cooperative Council (GCC) countries relied heavily on oil and gas as a primary source of income. As they employ oil and gas sales revenues to improve economic development, which led to unprecedent modernisation and industrialisation in both urban and rural levels [2], [3].

As result, in 2011, the GCC countries consumed as mush oil and gas as Indonesia and Japan combined, with an average of 6% over last decades and it expected to be doubled by 2024 [4], [5]. The following points discuss the current energy consumption and the structure of energy usage in the gulf region.

2.1 The GCC countries: Energy consumption and structure of energy usage

The energy consumption of the GCC countries has been rising over the last decades. One of the main contributors of increasing the energy consumption is the population growth rate [2]. The number of populations in the GCC countries reached approximately 5.8 million inhabitants in 2019 [2]. In addition, based on United Nation data (2009), the average rate of population growth will increase 1.29% higher in (2010–2050) [6].

However, there are others energy consumptions' contributors such as, water desalination – as the GCC countries suffer from water scarcity and dissertation – low energy price, and high economic growth rate [1], [2], [7].

Moreover, a comparison study was made by Sweidan [2] to display the energy use, electricity consumption (kw/h) per capita and the CO_2 emission per capita of the GCC countries compared to three industrial countries (Japan, France, and UK), during the period (1971–2014). The results showed that for the energy use of the GCC is 2.3 times more than the three industrial countries as shown in Table 1. Furthermore, for the electricity consumption of the GCC, as described in Table 2, is larger than the individual of industrial countries by around 1.50 times. In addition, for CO_2 emissions of the GCC reached 1.78% during the period (1997–2014) and expanded to 2.49% during the period (2000–2014), as shown in Table 3 [2]. Therefore, the GCC countries require a serious efficiency policy intervention. In order to ensure the appropriate design of these intervention, it is important to first explore the structure of energy usage in each country of GCC.

2.1.1 The structure of energy usage

Fig. 1 illustrates a basic sectorial breakdown of energy consumption in each GCC countries representing the four main segments (electricity and cogeneration, industry, transport, and non-energy use) [4], [5]. This shows that the electricity sector is the highest energy consumption which accounts for 70% of total energy consumption in the GCC countries. Buildings represent a high portion of electricity consumption for all GCC countries. In addition, the industry sector accounts for near to 50% of total energy consumption, Qatar represents the largest portion of industry consumption in the GCC countries. Furthermore, transport sector accounts for almost 30% of total energy consumption, Saudi Arabia shares

the highest energy demand for transportation, where it is double of that of the other countries. This is due to its larger land area and size.

Based on the differing structure of energy use, the government of GCC countries have publicly noticed the unsustainable nature of energy consumption patterns and the tremendous waste of nature resources. As a result, the Gulf Cooperation Council (GCC) announced the current energy policy and strategies. Therefore, in order to address energy efficiency, it is vital to evaluate the current energy policy and targets, and its limitations.

Table 1: Energy use (kg of oil equivalent per capita) of the individual GCC and three industrial countries. *(Source: World Bank Development Indicators, and a comparison study by Sweidan [2].)*

Years	Energy consumption (kg of oil equivalent per capita)								
	Bahrain	Kuwait	Oman	Qatar	KSA	UAE	Japan	France	UK
1971	6.39	7.64	0.11	7.75	1.21	3.63	2.53	3.02	3.73
1980	7.80	7.62	1.00	14.80	3.19	6.94	2.95	3.47	3.52
1985	9.92	8.07	1.41	15.22	3.49	9.86	3.01	3.59	3.55
1990	10.56	4.34	2.33	13.70	3.55	10.98	3.55	3.83	3.60
1995	11.41	9.18	2.77	15.87	4.51	11.31	3.94	3.98	3.73
2000	11.99	9.13	3.34	18.44	4.71	9.99	4.08	4.14	3.79
2005	11.68	11.54	3.94	19.27	5.13	9.72	4.06	4.29	3.69
2010	10.21	10.70	6.15	15.53	6.76	7.46	3.89	4.02	3.23
2014	10.59	8.96	6.14	18.56	6.94	7.77	3.47	3.66	2.78
Avg.	**10.07**	**8.10**	**2.77**	**15.54**	**4.12**	**8.58**	**3.45**	**3.76**	**3.57**

Table 2: Electricity consumption (kW/h) per capita of the individual GCC and three industrial countries (in thousand). *(Source: World Bank Development Indicators, and a comparison study by Sweidan [2].)*

Years	Electricity consumption (kW/h per capita)								
	Bahrain	Kuwait	Oman	Qatar	KSA	UAE	Japan	France	UK
1975	2.63	4.17	0.15	3.80	0.53	2.32	4.03	3.25	4.49
1980	4.61	6.06	0.62	9.72	1.97	5.75	4.72	4.42	4.68
1985	15.93	8.17	1.47	10.07	3.07	8.63	5.33	5.26	4.83
1990	15.62	8.22	2.19	9.59	4.02	8.50	6.81	5.97	5.36
1995	20.55	13.15	2.58	10.74	4.93	9.40	7.70	6.62	5.58
2000	20.01	14.07	3.20	14.35	5.66	12.31	8.30	7.22	6.11
2005	21.33	17.08	3.92	15.46	6.62	12.28	8.54	7.65	6.27
2014	19.60	15.59	6.45	14.78	9.40	11.09	7.82	6.94	5.13
Avg.	**15.40**	**11.57**	**2.78**	**11.53**	**4.79**	**9.04**	**6.85**	**6.19**	**5.40**

Table 3: CO_2 emissions per capita of the individual GCC and three industrial countries. *(Source: World Bank Development Indicators, and a comparison study by Sweidan [2].)*

Year	CO_2 emissions per capita (t)								
	Bahrain	Kuwait	Oman	Qatar	KSA	UAE	Japan	France	UK
1971	13.80	33.88	2.80	76.64	9.80	75.98	7.55	8.81	11.82
1975	21.59	16.42	8.23	66.64	11.2	56.05	7.77	8.24	10.74
1980	21.92	17.98	5.24	58.53	17.39	35.40	8.11	9.13	10.29
1985	24.31	16.77	5.78	33.43	13.09	35.89	7.58	7.06	9.90
1990	25.06	24.29	6.28	24.71	11.38	27.96	8.87	6.42	9.71
1995	26.29	34.04	7.21	61.91	12.55	28.85	9.43	5.86	9.28
2000	28.05	26.12	9.65	58.64	14.3	35.68	9.62	5.95	9.2
2005	21.60	31.43	11.90	58.92	16.63	25.36	9.70	6.10	8.98
2010	23.59	29.89	15.59	40.74	18.91	19.44	9.15	5.43	7.86
2014	23.45	25.22	15.44	45.42	19.53	23.30	9.54	4.57	6.50
2016	22.23	24.95	14.17	38.90	17.37	22.04	8.94	NA	5.78
Avg.	**23.57**	**23.76**	**9.03**	**52.29**	**14.88**	**34.46**	**8.77**	**6.85**	**9.34**

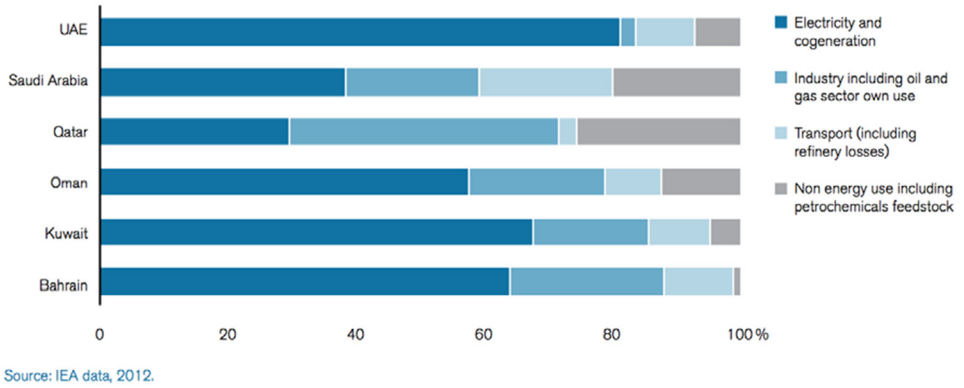
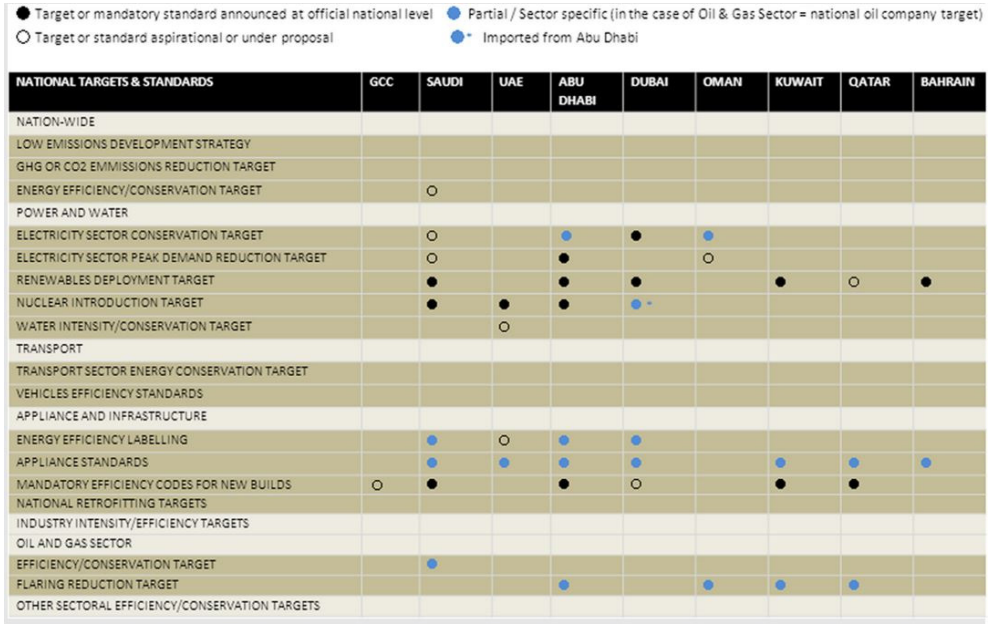


Figure 1: Basic sectorial breakdown of energy consumption in the GCC countries [4], [5].

3 THE CURRENT ENERGY POLICY AND TARGETS IN THE GCC, AND ITS LIMITATIONS

Since the global awareness of sustainability has started to set a trend amongst decision-makers and developers in all the GCC countries. A remarkable progress has made toward clean energy targets and efficiency strategies by members of GCC. Moreover, a coordinating project made by Chatham House with regional partners of the GCC to consider energy targets and strategies [8]. Fig. 2 illustrates the basic overview of energy targets and strategies of the GCC countries made by Chatham house, where the black dots represent targets and standards set at national level, blue dots represent targets applied to a specific part of the economy, and the outlined dots show targets and standards at the study or proposal stage [8].



NATIONAL TARGETS & STANDARDS	GCC	SAUDI	UAE	ABU DHABI	DUBAI	OMAN	KUWAIT	QATAR	BAHRAIN
NATION-WIDE									
LOW EMISSIONS DEVELOPMENT STRATEGY									
GHG OR CO2 EMMISSIONS REDUCTION TARGET									
ENERGY EFFICIENCY/CONSERVATION TARGET		○							
POWER AND WATER									
ELECTRICITY SECTOR CONSERVATION TARGET		○		●	●	●			
ELECTRICITY SECTOR PEAK DEMAND REDUCTION TARGET		○		●		○			
RENEWABLES DEPLOYMENT TARGET		●		●	●		●	○	●
NUCLEAR INTRODUCTION TARGET		●	●	●	●*				
WATER INTENSITY/CONSERVATION TARGET			○						
TRANSPORT									
TRANSPORT SECTOR ENERGY CONSERVATION TARGET									
VEHICLES EFFICIENCY STANDARDS									
APPLIANCE AND INFRASTRUCTURE									
ENERGY EFFICIENCY LABELLING		●	○	●	●				
APPLIANCE STANDARDS		●	●	●	●		●	●	●
MANDATORY EFFICIENCY CODES FOR NEW BUILDS	○	●		●	○		●	●	
NATIONAL RETROFITTING TARGETS									
INDUSTRY INTENSITY/EFFICIENCY TARGETS									
OIL AND GAS SECTOR									
EFFICIENCY/CONSERVATION TARGET		●							
FLARING REDUCTION TARGET				●		●	●	●	
OTHER SECTORAL EFFICIENCY/CONSERVATION TARGETS									

Figure 2: Targets and standards affecting energy use in the GCC countries. *(Source: GCC Energy Intensity Project, 2013.)*

Furthermore, Table 4 illustrates a summary of the energy targets and standards for the GCC countries. This shows the most significant efforts of GCC regarding coordinated energy targets and strategies. Dubai launched the first integrated energy strategy in the region – a plan for energy diversification and efficiency targets for 2030 in 2011 [5], and Abu Dhabi was a head as being the first region to set renewable energy targets of 7% by 2020 in 2009 [4], while Saudi Arabia have high ambitious to expect that by 2032 renewable energy with nuclear baseload will reduce fossil fuel generation to meet peak demand during the summer month [5]. Regarding building efficiency-standards, most of GCC countries are considering the issue related to reducing energy demand by pursing innovation building standards and codes [4], [8]. The most progressive building standards in the region are in Abu Dhabi and Dubai in the UAE, and Qatar. Abu Dhabi's Estidama Pearl Rating System, which began to be applied in 2010, was the first of its kind in the region to highlight on international best practice but with adaptations to suit the local climatic conditions, the Green Building Code (GBC) in Dubai is the only established green code in the region, while Qatar has pioneered the Global Sustainability Assessment System (GSAS) in which energy and water efficiency.

On the contrary, the GCC countries have no energy targets to reduce fuel demand in transport or standards for vehicle efficiency. As for transport sector, although there is a remarkable growth in car use and sprawl urbanization, this requires to think efficiency in transport at earlier stage than in power sector [8]. However, there are several steps toward diminishing transport emissions. As municipal authorities have developed plans for public transport in the last couple of years. Each country of GCC now has plans to introduce new metro systems such as Dubai's metro system [8]. In addition, in 2003, the Gulf Standard Authority (GSA) set a mandatory vehicle exhaust emission standard for new imported

Table 4: A summary of the energy targets and standards for the GCC countries.

Country	Administrative institution dealing with energy policy	Energy targets in the GCC countries, mid-2013			
		Efficiency	Renewable energy (RE)	Nuclear	Under study
KSA	Electricity load management and demand side management (ECRA, Saudi Arabia)	• 14% reduction of electricity peak demand planned by SEEC and 8% consumption reduction by ECRA	• 5GW of solar power by 2020. • By 2032, RES are planned to reach 54.1 GW by 23.30% from power generation capacity (PGC) • 41 GW solar energy (25 GW GSP/ 16 GW PV), 9 GW from wind, 4 GW thermal + waste energy	• 17 GW Reduction 18–20% PGC by 2032	• Bring energy intensity in line with G7 countries (SEEC).
Kuwait	Environment Public Authority	N/A	• The share of RE is planned to reach 1% by 2020 and will be expanded up 15% by 2030	N/A	N/A
Qatar	Tarsheed campaign (KAHRAMAA, Qatar General Electricity and Water Authority), Qatar	• 20% decrease in per capita electricity consumption by 2017 • 35% reduction in per capita water consumption by 2011	• RE is planned to reach 2% by 2020. • By 2030, RE share will reach 20%	N/A	N/A
Abu Dhabi	Comprehensive Cooling Plan (Cooling Taskforce, Executive Affairs Committee, Abu Dhabi)	• Reduce electricity demand by 15% of 2010 demand by 2020 (4,500 GWh/year out of a total demand	• 800 MW of solar power by 2020, with 7% RE share	• 4 nuclear power plants (5.6 GW) planned for 2020 and will be extended 12% by 2030	N/A

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Table 4: Continued.

Country	Administrative institution dealing with energy policy	Energy targets in the GCC countries, mid-2013			
		Efficiency	Renewable energy (RE)	Nuclear	Under study
Dubai	Dubai Supreme Council of Energy (DSCE) (est. 2009)	• Reduce BAU projected power consumption by 30%, by 2030	• The share of RE reach 1% by 2020 and will be increased up to 5% by 2030	• 12% nuclear-powered electricity sourced from Abu Dhabi by 2030	N/A
Oman	Reduction of losses in electricity transmission (AER, Oman)	• Reduce transmission and distribution losses in power sector from 14% in 2010 to 10% in 2014	• The share of RE reach 10% of total electricity consumption by 2020	N/A	• Electricity peak demand reduction target
Bahrain	Public Commission for the Protection of Marine Resources, Environment and Wildlife	N/A	• The share of RE is planned to reach 5.7% from PGC by 2030	N/A	N/A

vehicles into the GCC countries. Moreover, Abu Dhabi and Qatar have introduced legislation to curb transport emission beyond the GSA regulations. Abu Dhabi air quality established to accomplish the strategy encouraging a switch to compressed natural gas and clear diesel with an average 70% by 2013, while Qatar was the only state that has made an explicit commitment to a low carbon transport architecture which encourage road users to switch to rails and public transport [5]. Similar to industry sector, the industrial efficiency-standard is absent although the Gulf Organization Industrial Committee (GOIC) aimed at saving power in 39 factories in the GCC, and achieved saving up to 30% energy use and 80% in water use [5].

3.1 The limitations of current energy policy and targets

In order to improve the current energy policy and targets of the GCC countries, it is crucial to first acknowledge the limitations that can hold back the progress and fragment the current energy targets, limitations such as the following, according to Lahn et al. [5] and Lahn and Preston [8]:

- Lack of strong coordination between authorities and agencies to formulate and implement these energy targets and strategies.
- Lack of awareness of natural resources' value.
- Lack of available reliable data and centralized data sets on which to measure. Energy consumption data at the national level are often given only in aggregated form and publicly available sectoral data is partial.
- Weak enforcement of existing efficiency regulations, the challenge is to create the regulatory capacity to ensure they are followed.
- The low price of energy (fuel, electricity and water) compared to the income of consumers made no incentive investing in energy efficiency projects.

Finally, all GCC countries show various procedures towards integrated energy targets and strategies in almost all fields, especially in efficiency-standards for buildings and renewable energy development. However, there is urgent need for establishing transport and industry energy targets, and efficiency-standards for vehicle and industrial in all countries of GCC. Otherwise, the GCC countries now have a long strategic clean energy targets and plans. Although these targets are addressing only energy savings not CO_2 emission reduction targets except for Abu Dhabi – the only state that set a strategic approach to reduce CO_2 emissions by 7% by 2020. Therefore, in order to improve the current energy targets that could also address the reduction of CO_2 emission in the GCC countries, it is important to review and discuss the previous studies that consider intensity targets and renewable energy targets in GCC countries.

4 THE POTENTIAL OF ADAPTING NATIONAL AND REGIONAL TARGETS LEVELS SOLUTIONS

This section reviews the previous studies that have investigated the efficiency of energy targets and standards and the potential of having intensity targets and renewable energy targets in the GCC countries, aiming for energy-efficiency and reduction of CO_2 emissions. One of these studies is Lahn and Preston's study [8] that investigated the main types of energy targets being pursed internationally and evaluated the benefits and drawbacks that might be taken into consideration for GCC countries. The results of study outlined that the government of China committed to a 20% energy intensity reduction targets by 2010 and with a 40–45% carbon intensity reduction targets by 2020. Hence, the targets related to CO_2 intensity may

offer several advantages such as energy efficiency and saving at national level and contribute to international climate agenda. The study concluded that the CO_2 per capita intensity targets would be more effective for countries with large population and significant absorption of energy production such as Saudi Arabia, UAE, and Oman than countries with smaller population (Kuwait and Qatar). In addition, it highlighted several drivers may help toward lower energy or CO_2 intensity targets, such as: the share of renewable energy, efficient-standard for building and vehicles, and energy-efficient of heavy industry. Moreover, the study of Nanduri [8] revealed that energy intensity is very useful for measuring energy efficiency although that CO_2 intensity indicators are likely to be more useful as a climate policy tool.

More study from The Chatham House report by Lahn et al. [5], the report highlighted the main aspects to manage energy in the GCC countries. Such as, policy coordination, where all countries have authorities responsible for each field and integrate them together. Targets, which include setting targets in promoting efficiency investment and now each GGC countries have announced several official and clean energy target and strategies. Improving infrastructure efficiency, which includes adapting building efficient standard, in order to work with rather than against the gulf's harsh climate. Raising the efficiency of appliances, which involve efficiency-standards for vehicle. Energy price reform, which include raising the electricity tariffs to force efficiency investment. Behavioural changes, which consider providing awareness to citizens on how to use energy and value the importance of natural resources. Measurement performance, which discuss the mechanism of measurement tool to evaluate the targets, to collect the adequate date for this evaluation process, and to ensure strong enforcement regulation for implementation.

Another study by Abdmouleh et al. [9], the study investigated regional targets and decision-makers, in order to formulate a set of recommendations on renewable energy in the GCC countries. The study began with investigating the potential of renewable energy in the GCC countries as the solar energy, wind energy and biofuel have constituted the largest potential in the region and then discussing the specific challenges that faced the GCC countries in developing alternative energy, such as the effect of high temperature and dust, the lack of detailed studies about the region potential and the lack of understanding the cost and benefits of biofuel. Furthermore, exploring the status of GCC countries to transform the energy system in order to achieve an efficient use of renewable energy including list of existing renewable energy project, policies considering target setting, improving industrial efficiency, energy price reform, and behavioural change. The results showed that there are first steps regards establishing new policies promoting renewable energy development. However, there are some gaps regarding market distortions targets, policy mechanisms, climate policy and institutional regulatory framework. Moreover, the study suggested recommendations that classified into first financial support, which consists of removing subsides and adapting new subsides in order to create a competitive market including renewable energy projects. Second, legislative support, which is adapting legislative mechanisms such RPS which mandates a certain fraction of using energy should come from a basket of specific technologies, such as wind and solar, or renewables in general in order to develop renewable energy development. Third, political support, which is changing the government's regulatory into an independent regulatory authority helps to encourage renewable energy development. environmental support, which is allowing renewable energy project which assist in reducing emissions such as the 10 MW PV plant in Masdar city and suggesting a strong infrastructure for transmission grid will be needed in order to transport electricity. The study concluded that the importance of governance in adapting national and

regional policies that play a key role in supporting renewable energy development and implementation.

Similar to the study by Reiche [1], the study is about transforming oil wealth of GCC countries into funding for renewable energy development and energy-efficiency. The study evaluated the governance of GCC countries and what obstacles faces the governance in transforming process of integrating renewable energy. Lastly, the study concluded that integrating renewable energy targets and strategies through the role of adapting national level targets and regional level targets, as well as international level targets can have a major impact in improving the current energy policy and targets of GCC countries by fostering the opportunity to the contribution of international climate change protection agencies.

Therefore, from reviewing the previous studies, the effectiveness of adapting appropriate national and regional target levels with emphasising the role of renewable energy targets and intensity targets can improve the current energy policy and targets in the GCC countries.

4.1 GCC on the national targets level

Setting appropriate national targets for energy conservation, there are some issues must be considered, such as the following [1], [5], [8]–[10]:

1. To establish CO_2 intensity targets, by ensuring the design of infrastructure grid, including power and water utilities and distribution industries, housing stock, and transportation, that is working with the harsh climate conditions of the Gulf region rather than against it
2. To provide energy-efficiency standards for all sectors, note that there no energy-efficiency standards for vehicle yet.
3. To integrate renewable energy targets by working on renewable energy development. One of main project in renewable energy development is Masdar city in Abu Dhabi.
4. To ensure the collection of available reliable data for each national target, in order to assist in reporting correctly data to target-makers, which could help in improving these targets.
5. To provide training and expertise in creating a mechanism that allow regular evaluation on the energy target to give feedback to the policy-making process, in order to allow maximizing progress towards meeting the energy policy target.
6. To increase the price of energy, by forcing the investors and designers to choose efficiency design.
7. To create strong enforcement of regulation, in order to ensure the implementation of energy targets.

4.2 GCC on the regional target level

The aim of GCC is to enhance the coordination, cooperation, and integration between all sectors. As the GCC Supreme Council highlighted the importance of joint environmental action for converging policies, unify environment laws and legislation, improving national and regional capacity, training of labour force, raising environmental awareness among citizen and conservation of natural resources. furthermore, the efforts made by GCC members of supreme council in planning integrated energy targets and strategies on regional level gained several advantages to GCC countries [1]. However, these energy targets and strategies needs to properly work on the expanding of national targets level (CO_2 emissions reduction targets, energy-efficiency standards, renewable energy targets, measurement of the

Table 5: A summary on main setting for national and regional targets levels.

Ref	Targets	Recommendations for energy targets in the GCC countries	
		National level	Regional level
[8]	CO_2 intensity targets	To ensure the design of infrastructure grid, including all involvement sectors inside this guide, must be energy-efficiency	To extend the design of infrastructure grid to reach all of GCC countries and share energy on regional level, to provide the grid of GCC connectivity and flexibility to send electricity and create transmission grid for transport
[5]	Efficiency-standards targets	Based on pervious target, providing energy-efficiency standards for all involvement sectors in the grid, for example: building and appliances, transportation and industrial	
[9]	Renewable energy targets	To work on the renewable energy development, for example, 10 MV PV plant in Masdar city	To extend the renewable energy development not just individual dynamic project but to work on coordinated integrated renewable energy projects for regional level
[5], [8]	Reporting data	To ensure the collection of complete adequate data for each national target in order to aid in reporting and the evaluation process	To ensure of clarity of data to help in improvement of regional level
[5], [8]	Measurement of performance of target	To create a mechanism that allow regular evaluation on the energy target to give feedback to target-makers, in order to improve the target	To extend this mechanism of regular evaluation on regional targets
[5], [8]	Strong enforcement regulation	To provide strong enforcement regulations to make sure all of investors and designers are following targets of national level	To extend this enforcement regulations on regional targets level
[5], [8]	Increasing energy price	To force investors and designers to choose energy-efficiency design to save more energy	To work on common price of energy in all of GCC on regional level

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performance of target, strong enforcement regulations and increase of energy price) to a higher regional targets level and also international targets level, in order to provide energy conservation at a higher level as possible. Finally, Table 5 shows a summary on main setting for national and regional targets level.

5 CONCLUSION

Regarding energy conservation, the GCC countries have recently adopted integrated-energy targets and strategies that addresses environmental issues. Such as, energy saving targets, renewable energy targets, efficiency-standards for buildings and appliance – note that there is an urgent need for efficiency standards in transport and industry in all countries. However, the government of GCC showed significant effort considering energy saving targets rather than CO_2 emission reduction targets.

Briefly, this paper discusses first the energy consumption and usage of GCC, second the status of efforts provided by the GCC government in managing energy, which included establishing of the current energy policy and target and exploring the limitations of these targets, and finally the potential of adapting national and regional solutions to improve the efficiency of energy targets and strategies and to reduce CO_2 emissions. As a result, this paper reveals the significance of main drivers considering managing energy. Such as, the importance of GCC governance, by pursuing innovative pilots in efficiency, clean energy plans, energy efficiency-standards and pricing reform. Moreover, the need for integration of renewable energy strategy, by implementing renewable energy targets that can enhance the efficiency of current energy policy and targets. Furthermore, the potential for greater effectiveness through cooperation at regional level, by extending of national targets to a higher regional level in order to increase efficiency to a higher level.

Bring all together, this paper provides an overall comprehensive review of cooperative approach of GCC in order to enhance energy conservation. However, there is need for a greater focus on the current energy policy and targets, especially on CO_2 emission reduction targets instead of energy saving targets, integrated renewable energy targets which have a high potential to impact on energy policy and targets. Therefore, it is crucial to work on targets that could have the potential to expand to a higher regional level and contribute to international climate change protection.

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REFERENCES

[1] Reiche, D., Energy policies of Gulf Cooperation Council (GCC) countries: Possibilities and limitations of ecological modernization in rentier states. *Energy Policy*, **38**(5), pp. 2395–2403, 2010. DOI: 10.1016/j.enpol.2009.12.031.

[2] Sweidan, O.D., The environmental and energy policies to enable sustainable consumption and production in the Gulf Cooperation Council countries. *Clean Technologies and Environmental Policy*, **23**(9), pp. 2639–2654, 2021. DOI: 10.1007/s10098-021-02184-y.

[3] Salahuddin, M. & Gow, J., Economic growth, energy consumption and CO_2 emissions in Gulf cooperation council countries. *Energy*, **73**, pp. 44–58, 2014. DOI: 10.1016/j.energy.2014.05.054.

[4] Abdulrahman Ghabra, N., Energy efficient strategies for the building envelope of residential tall buildings in Saudi Arabia. Department of Architecture and Built Environment, 2017.
[5] Lahn, G., Stevens, P. & Preston, F., Saving oil and gas in the Gulf, 2013.
[6] Ramadan, E., Sustainable urbanization in the Arabian Gulf region: Problems and challenges. *Arts and Social Sciences Journal Ramadan, Arts Social Sci J*, **6**(2), 2015. DOI: 10.4172/2151.
[7] Al-Maamary, H.M.S., Kazem, H.A. & Chaichan, M.T., Climate change: The game changer in the Gulf Cooperation Council region. *Renewable and Sustainable Energy Reviews*, **76**, pp. 555–576, 2017. DOI: 10.1016/j.rser.2017.03.048.
[8] Lahn, G. & Preston, F., Targets to promote energy savings in the Gulf Cooperation Council states. *Energy Strategy Reviews*, **2**(1), pp. 19–30, 2013. DOI: 10.1016/j.esr.2013.03.003.
[9] Abdmouleh, Z., Alammari, R.A.M. & Gastli, A., Recommendations on renewable energy policies for the GCC countries. *Renewable and Sustainable Energy Reviews*, **50**, pp. 1181–1191, 2015. DOI: 10.1016/j.rser.2015.05.057.
[10] Alnaser, N.W., Albuflasa, H.M. & Alnaser, W.E., The transition in solar and wind energy use in Gulf Cooperation Council countries (GCCC). *Renewable Energy and Environmental Sustainability*, **7**, p. 4, 2022. DOI: 10.1051/rees/2021034.

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SECTION 7
URBAN AGRICULTURE AND FOOD SOVEREIGNTY

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URBAN AGRICULTURE AND FOOD SOVEREIGNTY IN LATIN AMERICA: EXAMPLES OF NUTRITIOUS DIETS

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ABSTRACT
This article addresses the issue of food and spices grown and traded in Latin America, mostly in food gardens that are inside cities and metropolitan areas. The research question is: how can nutritious foods be available for consumers? Results from a series of projects about the useful flora consumed in nine countries of the New World, at the beginning of European colonisation and in modern times, using old manuscripts as secondary research source and semi-structured interviews of urban gardeners, farmers, traders, and consumers, as a primary source, have shown that native fresh fruits and vegetables are the option for Latin Americans. A total of 1,724 testimonies were gathered for two decades, from a percentage of 56.34 urban gardeners and farmers, from Cuba and Mexico to Southern Argentina and Chile, giving us a good number of food options that might improve family diets all over the world. Further promotion of urban agriculture and training on food and spice conservation techniques might boost the availability of nutritious diets for all.
Keywords: nutrition, urban agriculture, food sovereignty, sustainable cities, Latin America.

1 INTRODUCTION

For over twenty years we have been investigating flora consumption in Latin America. Research was initiated in Brazil, in 1998, and has been continued in several Spanish speaking countries, totalling nine so far (see Table 1). The project was first developed in the Portuguese Tropical Institute and later (2015) continued in the University of Lisbon. The main research objective was to assess the weight of native American useful flora consumed or applied as herbal remedy, in relation to exotic plants introduced later. From the New World we further investigated the Old World, namely Asia (2013–2015) and Africa (2017–2019). Methodology used testimonies of food plants growth in front and backyards in Latin American cities (1998 onwards). Trade of nutritious flora was also added to the research after 2004, in Mexico and Peru, followed by Brazil over gain.

Current contribution will only focus food plants and spices that are part of Latin American peoples' diets, as it would be impossible to summarise all findings in one single paper. As Henseleit [1] wrote, it is a controversial discussion whether consumers are taking care of environmental issues when buying food. Under the assumption that the survival of plant species mentioned in early colonisation manuscripts provided a fair indicator of environmental sustainability of both native and exotic flora introduced in the Americas, a secondary objective became the assessment of the survival of vegetable species, collected from the wild and cultivated through times.

The research question for this contribution is: How can nutritious foods be available for consumers? In fact, both Brazil that has 210,867,954 inhabitants, and Mexico, with 130,759,074, have a high percentage of urban population, respectively 84% and 78% [2]. As the majority of Latin Americans are urbanites, the option for this project was to target the urban realm, because some residents grow food, spices, and medicinal plants, in order to improve household nutrition and health, as previous research found [3].

Poverty reduction in the Americas has been an issue for the United Nations, as far as the Millennium Development Goals are concerned. Good governance and effective institutions


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Table 1: Surveys conducted in Latin America [17].

Cities and countries	Semi-structured interviews (n)	Urban gardeners and farmers (%)	Mission years
1. Belém, Brazil	570	97.3	1998, 2005
2. Presidente Prudente, Brazil	280	100	1999
3. Recife, Brazil	50	6.0	2019, 2020
4. S. Luís, Brazil	100	90.0	2010
5. Santarém do Pará, Brazil	50	64.0	2006, 2007
6. Santiago Metropolis, Chile	132	84.1	2002, 2003, 2005
7. Iquique, Chile	75	64.0	2012
8. Central Mexican Metropolis	100	42.0	2004, 2006
9. Lima, Peru	34	0.0	2004
10. Piura, Peru	40	0.0	2016
11. Habana, Cuba	50	94.0	2009
12. San José, Costa Rica	43	69.7	2010
13. Rio Cuarto, Argentina	100	80.0	2011
14. Colonia del Sacramento, Uruguay	50	48.0	2011
15. Panamá City, Panama	50	6.0	2017
Total or average	**1,724**	**56.34**	**–**

are crucial to sustain the trend in success examples, as recent literature suggests [4]. This aspect provides justification to further investigate the availability of nutritious plant species so as to offer national governments evidence of ways to better explore their own food environments. Facts and figures about the methodology used in this project will be presented next, followed by the results and the conclusions.

2 METHODOLOGY AND MATERIALS

The project started with surveys to urban agriculture practitioners in Belem, Amazonia, and Presidente Prudente, S. Paulo State, in Brazil, and continued three years later in Santiago, the capital of Chile. After 2004, food, medicinal plant traders and wild herb collectors were also targeted, vis a vis the great importance of herbal remedies for urban gardeners, registered in both countries. In the last decade the methodology evolved from primary data gathering into a twofold methodological approach:

(1) Archival investigation about food plant species, spices, and medicinal flora existent from the 16th to the 17th centuries, in Portuguese and Spanish speaking countries, the so-called first globalisation [5]. Manuscripts written by local Indians [6]; by travellers and settlers [7], [8]; and by Catholic priests [9]–[15] were selected using recent publications, historical archives, and libraries. This phase allowed us to examine secondary data about peasantries in the initial colonisation years, landscape descriptions of the geographical locations under scrutiny, as well as all flora uses reported.
(2) Fifteen surveys were conducted in cities, metropolitan areas, and rural settings located in alluvial islands of the Brazilian Amazon Basin, using face-to-face semi-structured interviews, an ongoing process. Table 1 summarises fieldwork done from 1998 to 2020

in Latin America, providing data about the number of testimonies, the percentage of gardeners and farmers interviewed, and the scientific missions accomplished per year.

The methodological process was continued with the botanical identification of flora mentioned in the first globalisation manuscripts and the primary data gathered during the interviewing phase, so as to compare their uses in modernity and in early colonisation years, to finalise with the evaluation of useful flora evolution through times. This research process used the Missouri Botanical Garden database, available online [16], and allowed to assess which species had vulnerable status or whether flora existent in the 16th and 17th centuries had been depredated (see Figs 1 and 2).

Figure 1: Corn from Argentina.

Figure 2: Quinoa, from Iquique, Chile.

3 RESULTS AND DISCUSSION

A total of 672 different plant species have been recorded through fieldwork conducted along two decades, about two thirds of which were native American flora. Therefore, a good array of nutritious food plants is available in home-gardens and peri-urban farms, in informal and formal trading posts, widely diverse and usually accessible to the Latin American urbanites. Food species were not the only aim of the project, as said, and thus spices and medicinal plants are part of the research. Earlier contributions had herbal remedies as the primary concern because they constitute the majority of the flora gathered [17], [18]. Current paper will only focus food and spices cultivated and traded in the New World, as the main research objective was to assess the weight of native American useful flora consumed in relation to exotic plants introduced later.

Results show that nutritious native and exotic flora mentioned in 16th and 17th century manuscripts did not disappear from local peoples' diets, even though food plants such as rice, potatoes and corn dominate as staples in the nine investigated countries (see Table 2). As to the bread, it is usually baked with wheat. Potatoes and corn (Fig. 1) are, by the way, American food species such as pumpkins, beans, sweet potatoes (*Ipomoea batatas*), amaranth or Inca wheat, cassava, and quinoa (Fig. 2). Inca wheat (*Amaranthus caudatus*) was mentioned by Garcilaso de la Vega [6], and beans by the Jesuits Jose de Anchieta, Cardim and, again by the Spanish Vega [6], [9], [12].

By country, the record was that potatoes and corn are basic food in Peru and in Chile; in Peru, yacón (*Polymnia sonchifolia*), a tuberous root is consumed to lower sugar levels, recommended to diabetes patients [19]. Cassava was a preference in Brazilian Amazonia,

Table 2: Food plants and spices usually consumed in Latin America, in the beginning of European colonisation and nowadays. *(Source: Author's surveys and [16].)*

Vernacular names	**Scientific names**	**Countries**	**Manuscripts (year)**
1. Amaranth, Inca wheat	*Amaranthus caudatus* L. AMARANTHACEAE	Ar, Br, CR, Ch, Me, Pe	Vega (1609)
2. Apium	*Appium graveolens* L., *A. sellowianum* H. Wolff., *A. leptophyllum* (Pers.) F. Muell. ex. Benth. APIACEAE	Br, Ar, Ur	Cardim (1625)
3. Apple	*Malus domestica* (Suckow) Borkh. ROSACEAE	All	Vega (1609), Vieira (1638), Oviedo (1526)
4. Avocado	*Persea americana* Mill. LAURACEAE	All	Oviedo (1526), Vega (1609), Arriaga (1621)
5. Banana	*Musa paradisiaca* L. MUSACEAE	All	Acosta (1590), Cardim (1625), Oviedo (1526), Vega (1609)
6. Beans	*Phaseolus vulgaris* L. FABACEAE	All	Anchieta (1610), Cardim (1625), Vega (1609).
7. Caja	*Spondias mombim* L. ANACARDIACEAE	Br	Cristovão de Lisboa (1627)
8. Cara	*Dioscorea dodecaneura* Vell DIOSCOREACEAE	Br	Anchieta (1610), Cardim (1625)
9. Carrot	*Daucus carota* L. APIACEAE	Br, Pa, Pe, Ar	Oviedo (1526)
10. Cashew	*Anacardium occidentale* L. ANACARDIACEAE	Br, Cu, CR, Pa	Anchieta (1610), Cardim (1625), C. Lisboa (1627)
11. Cassava	*Manihot esculenta* Crantz EUPHORBIACEAE	Br, CR, Cu, Pa, Pe	Caminha (1500), Oviedo (1526), Anchieta (1610), Cardim (1625), Acosta (1590), C. Lisboa (1627),Vieira (1652)
12. Chicory	*Eryngium foetidum* L. APIACEAE	Br, CR, Cu, Pa, Pe	Oviedo (1526), Vega (1609), Cardim (1625)
13. Chilli pepper	*Capsicum annuum* L. SOLANACEAE	All	Oviedo (1526), Vega (1609), Acosta (1590), Anchieta (1610), Arriaga (1621)
14. Cocoa	*Theobroma cacao* L. MALVACEAE	All	Acosta (1590), Vieira (1652)
15. Coconut	*Cocos nucifera* L. ARECACEAE	Br, Cu, CR, Me, Pa, Pe	Oviedo (1526), Acosta (1590), Anchieta (1610),Cardim (1625)

Table 2: Continued.

Vernacular names	Scientific names	Countries	Manuscripts (year)
16. Coriander	*Coriandrum sativum* L. APIACEAE	Ar, Ch, Br, Pa	Anchieta (1610), Cardim (1625), Vega (1609)
17. Corn	*Zea mays* L. POACEAE	All	Oviedo (1526), Acosta (1590), Anchieta (1610), Cardim (1625), Vega (1609), Arriaga (1621), Ovalle (1646), Ruiz de Montoya (1639), Vieira (1654)
18. Ginger	*Zingiber officinale* Roscoe ZINGIBERACEAE	All	Acosta (1590), Anchieta (1610), Vieira (1675)
19. Guava	*Psidium guajava* L. MYRTACEAE	Br, Ch, Me, Pa, Cu, CR	Oviedo (1526), Vega (1609), Vieira (1654)
20. Laurel	*Laurus nobilis* L. LAURACEAE	All	Oviedo (1526), Vieira (1645)
21. Lemon, Lime, Citron	*Citus limon* (L.) Osbeck, *C. aurantifolia* (Christm.) Swingle, *C. medica* L. RUTACEAE	All	Oviedo (1526), Vega (1609), Anchieta (1610), Cardim (1625)
22. Lentils	*Lens culinaris Medik* FABACEAE	Br, Ch	Anchieta (1610), Viera (1694; 1655, 1670–1675)
23. Oranges (sweet and sour)	*Citrus sinensis* (L.) Osbeck, *C. aurantium* L. RUTACEAE	All	Oviedo (1526), Vega (1609), Anchieta (1610), Cardim (1625), Acosta (1590)
24. Papaya	*Carica papaya* L. CARICACEAE	Br, Ch, Pa	Oviedo (1526)
25. Parsley	*Petroselinum crispum* (Mill.) Fuss. APIACEAE	All	Anchieta (1610)
26. Passionfruit	*Passiflora edulis* Sims PASSIFLORACEAE	Ar, Ch, Cu, Me, Br, CR	Cardim (1625), Lisboa (1627)
27. Peach	*Prunus persica* (L.) Batsch. ROSACEAE	Ar, Ch, Pa, Pe	Oviedo (1526), Vega (1609)
28. Peanuts	*Arachis hypogaea* L. FABACEAE	All	Vega (1609), Cristovão de Lisboa (1627)
29. Physalis, Camapu	*Physalis* sp. SOLANACEAE	Br, Pe	Anchieta (1610)
30. Pineapple	*Ananas comosus* (L.) Merr. BROMELIACEAE	Br, Ch, Pa, Pe	Oviedo (1526), Vega (1609), Anchieta (1610), Cardim (1625), Lisboa (1627)

Table 2: Continued.

Vernacular names	Scientific names	Countries	Manuscripts (year)
31. Pomegranate	*Punica granatum* L. LYTHRACEAE	All	Oviedo (1526), Vega (1609), Vieira (1651)
32. Potato	*Solanum tuberosum* L. SOLANACEAE	All	Oviedo (1526), Vega (1609), Anchieta (1610), Arriaga (1621)
33. Pumpkin	*Cucurbita moschata* Duchesne, *C. pepo* L. CUCURBITACEAE	Br, Me, Pa, Pe	Oviedo (1526), Vega (1609), Anchieta (1610), Cardim (1625), Anchieta (1610)
34. Quinoa	*Chenopodium quinoa* Willd. AMARANTHACEAE	Ar, Ch, Pe	Acosta (1590), Vega (1609), Arriaga (1621)
35. Rice	Oryza sativa L. POACEAE	All	Caminha (1500), Anchieta (1610), Vega (1609)
36. Soursop	*Annona muricata* L. ANNONACEAE	Br, Pe, Pa	Oviedo (1526), Vega (1609), Vieira (1672)
37. Sugar cane	*Saccharum officinarum* L. POACEAE	All	Anchieta (1610), Vieira (1649–1667)
38. Tuna and Nopal	*Opuntia* sp. CACTACEAE	Me	Acosta (1590)
39. Wheat	*Triticum* sp. POACEAE	All	Caminha (1500), Vieira (1642–1699)
40. Wine, Grapes	*Vitis vinifera* L. VITACEAE	All	Caminha (1500), Oviedo (1526), Vega (1609), Vieira (1633), Anchieta (1610), Arriaga (1621), Cardim (1625)

Note: Ar = Argentina; Br = Brazil; CR = Costa Rica; Ch = Chile; Cu = Cuba; Me = Mexico; Pa = Panama; Pe = Peru; Ur = Uruguay.

where the iron and calcium rich leaf is cooked for several hours and eaten in stews and duck dishes. However, rice and beans are the most common staples consumed everywhere else in the country; pumpkins, beans and corn are grown together in Mexico and in Costa Rica. In this last country as in Panama, meaning in Central America, chayote (*Sechium edule*), otoi (*Xanthosoma sagittifolium*), or *Dioscorea* gender staples and vegetables are local preferences.

Horticulture species such as anti-anaemic watercress (*Nasturtium officinale*), European anti-inflammatory Appium (*A. graveolens),* the native species *(leptophyllum, sellowianum*), as well as basil leaf (*Ocimum basilicum*), were introduced by the Spaniards and Italian migrants during colonisation years and are widely consumed in Argentina and Uruguay, together with new Asian crops such as soybeans (*Glycine max*). The same innovative process can be applied to fruit crops, such as antioxidant noni (*Morinda citrifolia*) gardened and available in Havana plots and urban farms, as well as in S. Luis backyards (Fig. 3), in Brazil [17], [18]. However, in Mexico native tunas and the nopal cactus, as well as exotic species

(*Opuntia ficus-indica*) are ingested together in fish or meat dishes, to control blood sugar levels in diabetic consumers [18].

Of course the preferences usually go to native American fruits like the highly caloric and vitamin-rich avocado (980 calories per fruit); anti-ageing and mood enhancer cocoa; vitamin C rich acerola cherries (*Malpighia emarginata*); assai palm fruits (*Euterpe oleracea*), which juice is more nutritious than milk (Fig. 4); Physalis (vitamins A and C); guavas (vitamins A, B and C); soursops (complex B and C); diuretic pineapples; digestive papayas (vitamins A, B, C and D); the Chilean cherimoya (*Annona cherimola*); as well as the sedative passion fruit [18]. It's important to emphasize that most of these fruits come from selected tropical plants with small space requirements. That's the case of papaya (4 × 2.5 m), guavas (6 × 5 m), soursops (7 × 7 m). Exotic fruit trees like banana are also choices for urban gardeners (3 × 2 m), limes (7 × 7 m) and pomegranates (2 × 2 m), for similar reasons [20].

Figure 3: Noni from S. Luis, Brazil.

Figure 4: Assai from Belem, Brazil.

Urban agriculture is the growth of food species within the urban tissue or in peri-urban areas. More and more, food sovereignty is dependent on front- and backyard production, because both the 2019 corona pandemic outbreak and the recent increase in fuel prices (2022), due to conflicts spiralling almost everywhere in the world, and most particularly in Eastern Europe, turned food prices higher due to scarcity of cereals, fertilisers, and pesticides. Chemicals are, by the way, usually not used in urban agriculture, as the production is mostly organic. That tendency was already evident in 1998, in Belem, Brazil, where 52.3% of the urban gardeners interviewed used no fertilization, at all; only about 8.5% used chemicals; the remainder utilized fruit seeds (Assai), leftovers from the kitchens, and weeds from pots and home gardens, as well as chicken manure to fertilize their food gardens [18].

Fruit culture dominated in Brazil and in Chile, ranging from 95% in Belem to 65.5% in Santiago, whereas most of the trees produced nutraceutical fruits, such as guavas, acerola cherries, papayas, and in Santiago, Chile, most particularly avocados. Avocados were also found in Mexico, in Cuba and Costa Rica capitals, in biodiverse food gardens, where medicinal species rivalled with all sorts of citrus trees [18]. Coconuts grew in Recife and in Belem, Brazil, as well as other quite diverse type of *Palmae*, most endemic like *Bactris gasipaes* (Pupunha). Exotic trees imported from far away former Portuguese colonies were trees like *Mangifera indica* (mangoes, from India) and *Eugenia malaccensis* (Jambos, from Malaca, Malaysia).

Native nuts such as cashew, peanuts, and Brazil nuts (*Bertholletia excelsa*), are consumed everywhere in Latin America. Unlike the previous examples, cashew and Brazil nut trees have wider space requirements. Even so, cashew trees were abundant in S. Luis, Brazil. From

the early colonisation years, all citrus trees were introduced by the Portuguese and Spaniards, as Fernandez de Oviedo (1526) and the Inca Garcilaso de la Vega (1609) wrote, even though the so popular *Bixa orellana* fruit, which paste covered the Indian skin [7], is now a nearly forgotten plant species. Exception is Belem, where the small tree is cultivated in ten home-gardens investigated in 1998 (nearly 3%); the fruit was consumed as spice. The useful flora listed in old manuscripts doesn't possess a vulnerable conservation status [16].

Local vegetables like *Eryngium foetidum* (Chicory) and *Spilanthes oleracea* have an elective role in Amazon Brazilian diets, but the first one is also common in Central America (Panama and Costa Rica). The *Hibiscus sabdariffa* (vinagreira) is used to make healthy rice dishes in S. Luis, Brazil. Native chicory is a bitter herb mentioned both by Oviedo and Vega, a recognised medicinal species (see Fig. 5); it has anti-anaemic, anti-flu, anti-fever, and anti-diarrhoeal properties [12], [21]. As to jambu (*Spilanthes oleracea*) it is very rich in iron and vitamin C, also possessing healing effects. *Talinum triangulare* is an African *Portulacaeae*, one of the many plants brought to the Americas by the Portuguese; anti-anaemic, mineral rich (calcium, iron and phosphorous), with high protein content, the leaf is usually added to soups and bean dishes, in Brazil.

Figure 5: Native chicory from Panama City, Panama.

Figure 6: Stevia from Rio Cuarto, Argentina.

Chillies, onions, coriander, and parsley were adamant in all Brazilian cities researched, from Amazonia to the S. Paulo state city of Presidente Prudente. In this last interior town, investigated back in 1999, cassava was the main staple grown by the less wealthy gardeners that used the municipal Feed Prudente Programme [22]. As to Chile, in Santiago laurel was the most sought-after spice, because the leaf was also consumed in anti-flatulence teas. However, exotic species like ginger were bought in markets and supermarkets, as no evidence was found that urban gardeners interviewed in Latin America had interest in growing the rhizome in their front or backyards.

Urban agriculture is an environmentally sustainable activity among the surveyed food growers, even those who had to intensively irrigate their plot, as was the case with dry Iquique city in northern Chile [23]. In this case study, the urban gardeners cultivated their food and medicinal herbs using organic fertilization (43,8%), in special mulching with leaves and leftovers (13.3% of the gardeners), rabbit manure (2.7%), horse, goat and chicken manure (2.7% again). Other quite advisable ways to fertilize the soil were compost tanks, and avocado outer skin usage. Compost tanks were provided by La Pintana municipality researched back in 2002 and 2003, in Santiago, but in Iquique, there was no such program available, in 2012. Only three of the 75 interviewed in Iquique used chemical fertilizers.

Coming back to food species available in food gardens or peri-urban farms, native American sweeteners like stevia (*Stevia boliviensis,* in Fig. 6) are cultivated in Argentina. It replaces sugarcane in several households, particularly in case of diabetes diseases. As to spices, the preference goes to chilli peppers mostly everywhere in Latin America, another native plant species recorded in old manuscripts (see Table 2). In Brazil and in Mexico, chillies are kept in vinegar to make a hotter mixture ready to be cooked in traditional dishes. In the last city researched, Recife, in Brazil, the usage is to preserve chillies in sugarcane distilled cachaça [24].

That doesn't mean Latin Americans reject Old World spices, such as coriander, laurel, ginger, already mentioned, and oregano, or *Piper nigrum*, which therapeutic value has wide recognition. Training opportunities on spice and food species conservation are needed to build the skills of urban gardeners and the urbanites in general, in order to improve food environments in Latin America. The secondary objective of this paper, meaning, the assessment of the survival of vegetable species, collected from the wild and cultivated through times, was done while recognizing that plants mentioned in old manuscripts are still grown in food gardens today.

4 CONCLUSIONS

Food growth in cities can effectively contribute for the improvement in food security of the urban citizens. It is an advisable solution to tackle climate change as it works in physical resilience of urban realms and in behavioural changes among urbanites [25]. Staple foods like rice and wheat and drinks, like water and wine, were carried in the Portuguese caravels, as it is mentioned in the letter of Pero Vaz de Caminha, the chronicles writer who accompanied Pedro Alvares Cabral, during his first voyage to Brazil, officially considered as the discovery of the land of *Caesalpinia echinata*, so-called Brazil-wood tree [7], [24]. They are obviously some of the most consumed food species all over Brazil, as are local flora namely corn (*Zea mays*) and potatoes (*Solanum tuberosum*), but also in the Spanish-speaking countries of the Americas. Local staples as cassava, chayote, otoi (*Xanthosoma sagittifolium,* Fig. 7), and cará (*Dioscorea dodecaneura*), one of several *Dioscorea* gender species are also available in contemporaneity as they were in the 16th century [24].

Figure 7: Otoi from Panama City, shaded by other native species.

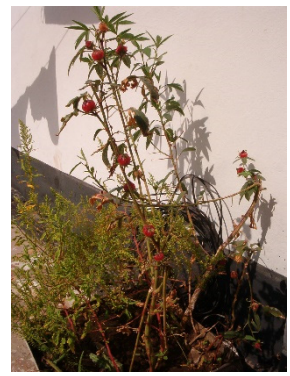

Figure 8: Vinagreira from S. Luis.

Exotic fruits and spices are eagerly sought after, yet native vitamin and mineral-rich species are preferred and cropped in urban gardens and farms. Latin America constitutes a

good example of option for nutritious daily food consumption, because the natural diversity of local flora has invited peoples from all latitudes to grow, trade and buy fresh fruits and vegetables through times, leading to positive consumer behaviour. Further promotion of individual and community food gardening (see Fig. 8) will improve the availability of nutritious vegetables and fruits that might ameliorate the daily diet of the less wealthy households. Current climate change situation, added to the 2019 pandemic outbreak, generated problems that require the development of innovative solutions, such as urban agriculture, to create more liveable urban areas. As seen in Tables 1 and 2, when practised with wise use of local resources, such as water and soil, without the application of chemical pesticides and fertilisers, food growth in the cities becomes a solution for nutrition sufficiency and environmental sustainability, without endangering our common future.

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REFERENCES

[1] Henseleit, M., Food for thought about environmental values and food demand. *Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research,* vol. II, pp. 522–525, 2008.
[2] Worldometers, Countries in the world by population. http://www.worldometers.info/world-population/population-by-country/ Accessed on: 7 Apr. 2022.
[3] UNDP, *Urban Agriculture. Food, Jobs and Sustainable Cities*, United Nations Development Programme: New York, 1996.
[4] Asadullah, N.N. & Savoia, A., Poverty reduction during 1990–2013: Did Millennium development goals adoption and state capacity matter? *World Development*, **105**, pp. 70–82, 2018.
[5] Carroué, L., *Atlas de la mondialisation. Une seule terre, des mondes*, Éditions Autrement: Paris, 2018.
[6] de la Vega, I.G., *Commentarios Reales de los Incas*, Pedro Crasbeeck: Lisbon, 1609.
[7] Caminha, P.V., Carta de Pêro Vaz de Caminha. *A Expedição de Pedro Álvares Cabral e o Descobrimento do Brasil*, ed. J. Cortesão, Imprensa Nacional/Casa da Moeda: Lisbon, pp. 127–141, 1500.
[8] Gaibrois, M.B., *Sumario de la Natural Historia de las Indias de Gonzalo Fernández de Oviedo*, Dastin: Madrid, 2002.
[9] Anchieta, J., Relação da Província do Brazil. *Vitae Padre Joseph Anchieta, Manuscrito Vitae*, eds R. Petrus, V. de Simon & S. Beretario, **153**, Archivum Romanum Societatis Iesu: Rome, pp. 54–66, 1610.
[10] de Acosta, J., *Historia Natural y Moral de las Indias*, Juan de León: Seville, 1590.
[11] Arriaga, P.J., *Extirpación de la Idolatría del Pirú*, Geronymo de Contreras: Lima, 1621.
[12] Cardim, F., *Tratados da Terra e Gente do Brasil*, ed. A.M. Azevedo, Comissão Nacional para as Comemorações dos Descobrimentos Portugueses: Lisbon, 1997.
[13] Franco, J.E. & Calafate, P., *Obra Completa Padre António Vieira*, vol. 30, Círculo de Leitores: Lisbon, 2013–2014.
[14] Ovalle, A., *Historica Relación del Reyno de Chile y de las Misiones y Ministerios que exercita la Compañía de Jesús*, Francisco Cavallo: Rome, 1646.
[15] Lisboa, C., *História dos Animais e Árvores do Maranhão*, Arquivo Histórico Ultramarino: Lisbon, 1627.
[16] MBG, Missouri Botanical Garden. http://www.tropicos.org. Accessed on: 7 Apr. 2022.

[17] Madaleno, I.M., Etno-Geografía de Flora Útil de Latinoamérica. Un análisis histórico comparativo de los siglos XVI y XXI. *Hacia una perspectiva integrada. Aportaciones de las Geografías Económica, Regional y de los Servicios para la cohesión y la competitividad territorial*, eds C. Gago, J. Córdoba, M.P. Alonso, R.M. Jordá & J. Ventura, pp. 63–67, 2021.
[18] Madaleno, I.M., *Estudo Etnogeográfico de Plantas Medicinais da América Latina*, Alêtheia Editores: Lisbon, 2013.
[19] Madaleno, I.M., Estudio Comparativo de Flora Consumida en Perú y Panamá en los Siglos XVI y XVII y en la Actualidad. *América Latina en las Últimas Décadas: Procesos y Retos*, eds F. Cebrián Abellán, F.J. Jover Martí & R.C. Lois González, pp. 1283–1295, 2018.
[20] Gomes, R.P., *Fruticultura Brasileira*, Nobel: S. Paulo, 1972.
[21] Cardoso, M.O., *Hortaliças não-convencionais da Amazônia*, Embrapa: Brazil, 1997.
[22] Madaleno, I.M., Urban agriculture supportive policies from two distant cities: Lisbon (Portugal) and Presidente Prudente (Brazil). *Urban Agriculture Magazine*, **4**, pp. 38–39, 2001.
[23] Madaleno, I.M. & Delatorre-Herrera, J., Medicina Popular de Iquique, Tarapacá. *IDESIA*, **31**(1), pp. 67–78, 2013.
[24] Madaleno, I.M., Useful flora grown and traded in Recife, Brazil. *WIT Transactions on Ecology and the Environment*, vol. 241, WIT Press: Southampton and Boston, pp. 207–218, 2020. DOI: 10.2495/SDP200171.
[25] Boeri, A., Longo, D., Orlandi, S., Roversi, R. & Turci, G., Community engagement and greening strategies as enabling practices for inclusive and resilient cities. *International Journal on Environmental Impacts*, **5**(1), pp. 1–14, 2022.

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REVIEW OF THE EFFECT OF COMMERCIAL FARM EXPROPRIATION ON THE FOOD RETAIL SECTOR IN SOUTH AFRICA

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ABSTRACT

To determine what effect commercial agricultural land expropriation will have on the accessibility of food and subsequently the retail sector in South Africa, this article comprehensively reviewed literature that identified lessons from recent land reform policies of other countries. Limited questionnaires and semi-structured interviews with selected individuals in the agricultural sector were also conducted to complement the literature reviewed. The focus is on large food retailers since these retailers are normally the anchor tenants in shopping centres. Subsistence farmers and convenience retailers such as those at filling stations and independent cafés do not form part of the study. It was found that land expropriation, especially expropriation without compensation (EWC), will have a direct negative effect on the availability, accessibility and cost of food if not done in a responsible manner and governed by law to ensure the process is transparent and fair. The implications are that the need for land reform and the ability of South Africa to produce food at prices which are affordable to the population should be balanced to avoid the economic collapse and social unrest as seen in some other countries.

Keywords: land reform, land expropriation, commercial agriculture, food security, food retail sector, South Africa.

1 INTRODUCTION

Land reform has been one of the most controversial and sensitive topics in South Africa since 1994. This study focuses on the expropriation of agricultural land, its impact on food security and more specifically, the effects of expropriation of commercial farms on the retail sector of the South African economy.

It is estimated that there are between 35,000 and 40,000 commercial farming units in South Africa (van Zyl [1]). The growing of crops, animal farming and mixed farming made up 86.3% of these units in 2017. The census, however, only included VAT-registered farming enterprises and thus not totally representative of the commercial farming landscape in South Africa (Kirsten and Sihlobo [2]).

Even though the total number of farming units remained relatively constant from 2007 to 2017, the income produced by these farms increased by 288% during the period (StatsSA [3]) due to technology, better cultivars and improved farming practices.

20% of farms in South Africa produce 80% of the food in formal retail outlets (von Bormann [4]). Not only do these farmers produce most of the food consumed by the estimated 59 million people in South Africa (StatsSA [5]), but they also export large amounts of produce globally, bringing much needed foreign currency into the country.

Uys [6] estimated that South Africa had 120,000 commercial farming units in 1980. These units decreased to approximately 40,000 in 2017. It is foreseen that this number will further decrease to 15,000 in the next 15 years (Gosling and Moolla [7]).

It is estimated that the South African population will be approximately 73 million people by 2050 and the demand for food will double. The demand for meat and milk is estimated to increase with 200% (von Bormann [4]).

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With the ever-increasing population, the pressure on food production will be higher than ever. Supermarkets are the major channel delivering the food to the population – they make up only 2% of the retail outlets in South Africa, but an estimated 60% of food is sold by them and the percentage is growing (Joubert [8]). According to the 2020 Pick 'n' Pay Annual Report [9], the five largest retailers for food and groceries account for between 50% and 55% of formal retail sales. Pick 'n' Pay further estimates that the size of the total food and groceries market of South Africa was R970 billion in 2020, 60% of which is considered to be formal retail.

Commercial farming constitutes 80% of the agricultural output in South Africa (Export.gov [10]). It is thus important to protect the commercial agricultural sector to produce the food necessary for the supermarkets, restaurants and take-away businesses to sell to the public. A large percentage of these outlets are situated in shopping centres. Although different challenges all have an impact on access to food, the focus of the present study is on the effect that land expropriation can have on the availability and price of food and the impact it will have on the distribution channels via the formal retail sector.

2 FOOD IN SOUTH AFRICA

The availability of food not the only factor contributing to food security – the type of food, utilization and access to food are equally important (see Fig. 1). Only 46% of the South African population is food secure, with 26% and 28% experiencing hunger or at the risk of hunger, respectively (Shisana et al. [11]). In general, most South Africans cannot afford a healthy diet (Temple and Steyn [12]).

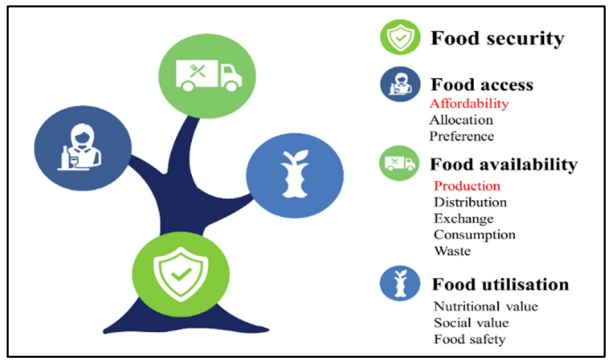

Figure 1: The three elements of food security. *(Source: Own interpretation from Pereira [13].)*

Hunger and food security are two separate issues. South Africa is currently food self-sufficient, either by local production or imports (Rahmanian [14]). It can thus be concluded that affordability is the main factor driving food insecurity in South Africa especially when it comes to healthier, nutritional foods.

Even though the agricultural sector as a percentage of the South African GDP declined from 10.66% in 1960 to 1.88% in 2018 (see Fig. 2), the sector remains a major player when it comes to offering employment in South Africa. It is estimated that 8.5 million people (16% of the population) depend directly or indirectly on agriculture for employment (von Bormann [4]). It is therefore crucial to ensure the agricultural sector is sustainable and remains on a growth trajectory.

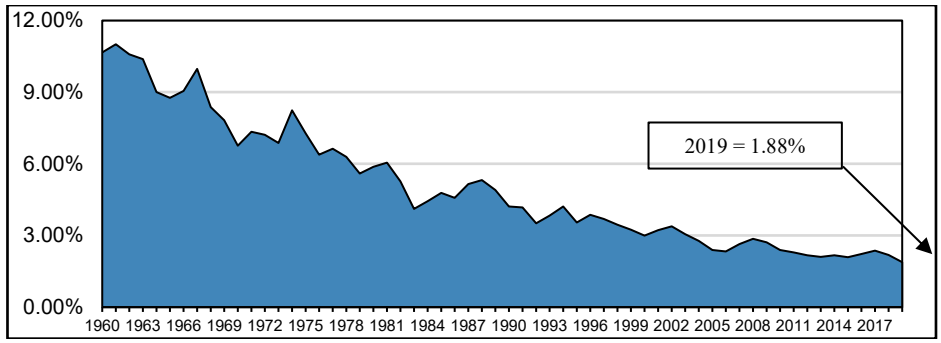

Figure 2: The agricultural sector as a percentage of total GDP [15].

Food price increases play a major role when it comes to social unrest (see Fig. 3). Although corruption by both the labour unions and the government is to blame (Lakmidas [16]), a major reason for these unrests is worker demands for pay increases above the official inflation rate (Bam-Yam et al. [17], Corcoran [18], Louw [19]). It is generally recognised that high food prices and a deterioration in food security may well trigger widespread violence especially in vulnerable populations (Lagi et al. [20]).

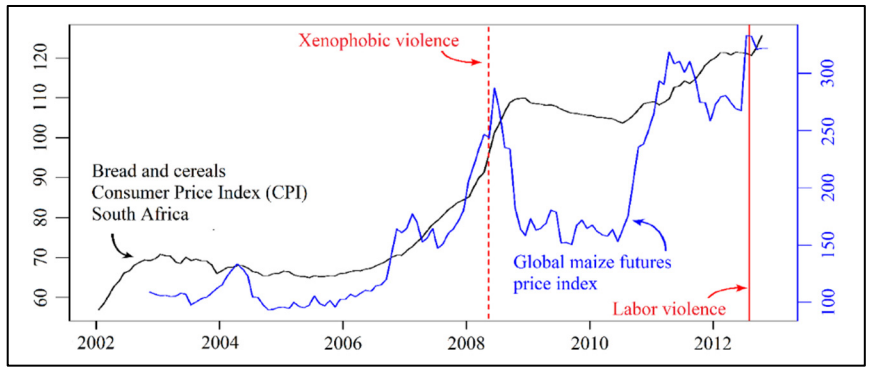

Figure 3: Food price index and major social unrest events in South Africa [17].

Food inflation is a significant variable to determine headline inflation in emerging markets (Mohanty and Klau [21]). Food and non-alcoholic beverages inflation were the third largest contributor to the average headline consumer price inflation in 2019, contributing between 13% and 15% to the total inflation rate (SARB [22]).

Food inflation is mainly driven by demand and supply factors. The demand factors can be controlled by monetary policy and disposable income of consumers as explained above, while supply factors will be a combination of policies to address structural issues (Louw [19]). Part of these factors includes the government policy on land expropriation.

3 THE SOUTH AFRICAN FOOD AND GROCERY RETAIL SECTOR

The informal market is relatively small in comparison with the formal market. Table 1 indicates that the total formal market is in the region of 83.6% of the total food and retail

sector. Hypermarkets, supermarkets and hard discounters made up 59.4% of the total sector in 2018 (MarketLine [23]).

Table 1: Key figures of the informal food retail sector.

Description	Amount
Informal food takeaways	> 50,000 shops
Turnover	> ZAR 90 billion a year
People employed	> 200,000
Hole in the wall spaza shops	> 70,000 shops
Spazarettes (informal supermarkets)	> 30,000 shops
Informal cash and carry turnover	> ZAR 150 billion a year
Hawkers or tabletop vendors	> 500,000 hawkers/vendors
Municipal fruit and vegetable trade from informal sector	± 60%

Based on an exchange rate of ZAR13.255/USD, the size of the total food and grocery sector was ZAR652.3 billion in 2018 (MarketLine [23]). In 2018 the growth declined to 3.7% mainly due to the exchange rate, droughts, rising interest rates, increasing fuel/energy costs and the unstable water supply which have contributed to less-than-ideal circumstances for the sector. The fierce competitiveness among the major players in the sector enabled the sector to continue to grow and MarketLine [23] forecasts that the sector will grow with an annual compounded growth rate of 5.1% up to 2023. The impact of Covid-19 was not accounted for and any possible impact of land expropriation was not cited in their findings.

The total South African food and grocery sector consists of food at 69% (ZAR450.3 billion), followed by drinks at 23% (ZAR149.8 billion), tobacco at 6% (ZAR37.6 billion) and household products at 2% (ZAR15.2 billion) (MarketLine 2020). It is thus safe to say that any possible external factor that has a major effect on food will lead to an impact on the total food and grocery sector.

4 THE PROPOSED EXPROPRIATION BILL 23 OF 2020

A significant step in the South African land reform process was reached when the Expropriation Bill 23 of 2020 was published in the Government Gazette on 9 October 2020. There is currently much controversy in the media regarding the possible consequences of the Bill. The Bill essentially provides for the following (Coetzee [24]):

- The expropriation of properties in the interest of the public.
- Expropriation without compensation in certain instances for public interest. This is the more controversial part of the current land reform debate over the last few years.
- Other matters connected to the Bill.

The Bill contains the following four key aspects (Coetzee [24]):

- A uniformed expropriation process.
- All expropriating authorities must adhere to the mandatory process.
- Determination of compensation.
- The final decision lies with the court.

Boshoff et al. [25] issued an opinion paper to clarify some of the misconceptions of the Bill and highlighted some inherent risks. Apart of the legal risk of litigation, the following two risks were identified:

- The political left may use it as a tool to use expropriation without compensation to gain support. If the expectations of the landless people and the political left are not aligned to the actual provisions and intent of the Bill, it may pose challenges in the future.
- Inaccurate and sensationalized comments in the media and other public sources could pose a danger to investor confidence in South Africa.

There are many opinions in the public domain on what the impact of land expropriation without compensation will be on the current land owners and their personal wealth. However, the focus of this study is rather on the impact on the South African food security, food inflation, the retail sector and the overall economy. The major concerns are the following:

- There is no consensus if it will be necessary to amend Section 25 of the Constitution to allow expropriation without compensation.
- The negative impact on food security if commercial farmers do not remain on the farms (Advisory Panel on Land Reform and Agriculture [26], High-Level Panel on the Assessment of Key Legislation and the Acceleration of Fundamental Change [27]).
- If the agricultural sector is seriously damaged due to a fast-track land reform policy, the South African economy can collapse as in the case of Zimbabwe (Hlomendlini and Makgolane [28]) and in Venezuela.
- Commercial farmers will be hesitant to invest further to enhance productivity because of uncertainty on their continued ownership (Advisory Panel on Land Reform and Agriculture [26]).
- Without guaranteed ownership of the farms financial institutions will be extremely hesitant or unwilling to finance farmers for capital investment.
- Expropriation without compensation will not accelerate land reform, simply because the State will become the owner of the land and nothing prevents the State to expropriate land from black farmers to benefit the elite (Free State Agriculture [29]).
- The Bill in its current form is not only applicable to agricultural properties but all types of properties i.e., immovable, movable and even intellectual property (Merten [30], Mabasa [31]). In its current form the Bill can have far wider economic consequences than just on the agricultural sector.
- Unreliable and incomplete information on the progress of land reform is driving policy decisions. A common theme in the research is that land reform is too slow and further interventions are necessary. However, Kirsten and Sihlobo [2] is of the opinion that the progress of land reform is underestimated due to poor record keeping. And estimate that the various forms of land reform, bringing the total to 15.5 million hectares, equivalent to 67% of the 2030 NDP target.

Even with the assumption that these figures reflect the current land reform progress more accurately, it does not confirm that the progress is acceptable to the majority of the South African population.

There are various examples of fast-track land reform programmes all over the world where these countries paid a high price. These include Venezuela, Ethiopia, Vietnam, Romania, Portugal, Spain and Zimbabwe. Spain, Vietnam and Portugal, however, realized the harmful effects on their economies and retracted the policies. The two most recent cases which is still suffering from the consequences of their policies are Venezuela and Zimbabwe.

In both Venezuela and Zimbabwe large commercial farming units were expropriated without compensation and divided into smaller units in an effort to uplift the poor communities, especially in rural areas. The major lessons from these countries are the following:

- Fast-track land reform was triggered by the slow pace of reform under the previous policies.
- A substantial decline in economic output in both the agricultural and manufacturing sectors.
- A decline in their GDP.
- Negative investor confidence.
- The policies were plagued by political agendas.
- Corruption by State officials in allocating the farms.
- No legal recourse or framework where the previous owners could challenge the expropriation.
- Land invitations with no support or protection from the police for the current owners.
- New owners were not given full title to the properties.
- No or very limited post settlement support.
- No training and development to grow these farms into commercial units.
- Food shortages and hunger.
- Increased poverty.
- Social unrest.
- Hyper-inflation.
- A drastic devaluation of their currency.

Irresponsible land expropriation will have drastic consequences not only to the food sector, but the whole economy of a country. In turn, this will inadvertently have an impact on the total retail sector of which Venezuela and Zimbabwe are prime examples where their land reform policies had a catastrophic impact on their inflation and exchange rate and the economy as a whole. No retailer can operate in a hyper-inflation environment. As the cost of food increases, retailers will have to adjust their prices accordingly. Consumers will change their buying habits in order to survive, thereby putting other markets in the retail sector under pressure, not only the food sector. Salaries and wages do not necessarily increase at the same rate as inflation, leaving many people unable to buy food. This in turn leads to social unrest and violence which cause physical damage and loss of property. In an effort to stop the ever-increasing spiral of food prices Venezuela and Zimbabwe imposed price restrictions. Since producers were unable to continuously supply at a loss, this led to further shortages which further fuelled the inflation rate.

Land expropriation in South Africa is not new. The current Expropriation Act of 1975 predates the Constitution and it is necessary to amend it to comply with the current requirements of the Constitution. Even though expropriation without compensation is only proposed in the Expropriation Bill of 2020, there are similarities with the current land reform programmes and those that happened in Venezuela and Zimbabwe. These indicate some vulnerabilities/pitfalls in the system and include:

- Decline in agricultural output of the farms that have been expropriated.
- Lack of post settlement support for the beneficiaries.
- Beneficiaries do not receive full title to the properties and are unable to obtain finance for investment capital. Current lease agreements offered by the State of up to 30 years are not sufficient. In countries like Zambia the leases are 99 years. This will motivate farmers to invest for them and their offspring thereby growing the unit for optimum production.

- Under the current policies and laws remains the preferred form of ownership full title to the properties. This however comes with challenges because traditional social and off-register tenure arrangements are a reality for a large part of the population.
- Various instances of political agendas.
- Corruption by State officials.
- Increased trend in land invasions.
- Social unrest in times of high food inflation.
- The slow pace of land reform, although conclusive data is not available.
- The general assumption that land reform will lead to the overall wellbeing of the people of South Africa especially in poor rural areas.

The only factors not currently listed above are those that were as a result of the fast-track land reform in Venezuela and Zimbabwe. Currently South Africa is still a country governed by the rule of law and the protection of property rights in terms of the law. As soon as these factors disappear it is safe to say that the Venezuela and Zimbabwean scenarios may become a reality. The current proposal of expropriation without compensation is fuelled by these fears because of the similarities with Venezuela and Zimbabwe.

5 METHODOLOGY

A variety of current literature on recent land reform initiatives in other countries was comprehensively reviewed. To complement the review, limited questionnaires and semi-structured interviews with selected individuals in the agricultural sector were also conducted. Selected individuals in the agricultural sector were approached to participate in questionnaires and semi-structured interviews.

The selection of the participants was done by means of a combination of convenience sampling and snowball sampling. Braun and Clarke [32] describe convenience sampling as a common approach in participant-based research and it is used when the participants are easily accessible to the researcher. In this type of sampling, participants are almost always self-selected and do not necessarily bear a relationship to the wider population. Braun and Clarke [32] further state that snowballing is also a common sampling technique and often forms part of convenience sampling. In the case of snowballing, the sample is built up through the networks of the participants and the researcher. Seventeen completed questionnaires were received and analyzed.

The respondents have combined 410 years' experience in the agricultural sector divided into 95 years primary agriculture, 265 years secondary agriculture and 50 years other agricultural related activities.

More than half of the participants professed to have knowledge of the effect of expropriation and the outcome of these cases. All but one of these nine participants indicated that the ability to provide food decreased on average with 86% after expropriation. None indicated that the ability to provide food increased after expropriation.

Table 2 divides the participants categorised above further into their fields of experience. One participant may have more than one field of experience and the total will not correspond to the sample size of 17. The majority of the participants are involved in the financing of agricultural entities, such as farms or businesses. These individuals represent a wide range of backgrounds and land expropriation is of critical concern since it could influence the quality of credit extended to the borrower as well as his or her ability to collect the finance extended. Secondly, primary agriculture is represented by participants that are involved in the primary cultivation of agricultural products and have the capacity needed to farm on a successful commercial basis. Thirdly, executive directors of various agricultural companies are

represented. Their views bring another dimension to the feedback as these individuals normally have a much broader point of view.

Table 2: Field of experience of the participants.

Number of participants	Type of agriculture	Field of experience
13	Secondary agriculture	Credit granting and agricultural finance at agricultural financing houses and banking for various types of primary agricultural products and agricultural processing companies
1	Secondary agriculture	Development finance and training for upcoming farmers
5	Secondary agriculture	Directorship
6	Primary agriculture	Cultivation of produce i.e., livestock, fruit, wine, etc.
2	Other agriculture	Advice on security, structuring of transactions, contracts, etc.

6 FINDINGS

Various reasons for the decline in food production due to land expropriation were given, as summarized in Table 3. Individual ownership and medium to long term mentorship programmes to transfer skills will go a long way to ensure that these properties will continue to contribute to food production of South Africa and mitigate the negative effect on food inflation and the food retail sector.

Table 3: Reasons for the decline in food production on expropriated farms.

Reasons for the decline in food production	Number of times cited	%	Category
Lack of skills transfer and mentorship with regard to general, financial and human resource management	2	16.7%	Lack of skills 50.0%
No or limited commercial farming knowledge	4	33.3%	
No access to finance either for capital expenditure or working capital	2	16.7%	Lack of finance and title deeds 25.0%
No transfer of ownership/title on an individual basis	1	8.3%	
Withdrawal of support from previous owners.	1	8.3%	Other 25.0%
Infrastructure destroyed by beneficiaries.	2	16.7%	
TOTAL	**12**	**100.0%**	

Following from the above, the action items that could have contributed to the successful expropriation of these properties were analyzed. The responses were grouped into five categories as indicated in Table 4. Again, transfer of skills, mentorship and training, not only in the sort-term but also on a medium- to long-term basis, were at the top of the list. To farm successfully on a commercial level takes years of experience and skills transfer must take this into account.

Table 4: Actions that could have contributed to the successful expropriation of farmland.

Action items that could have been done	**Number of times cited**	**%**	**Category**
At least medium-term training and mentorship in management, financial and human resource skills	5	33.3%	Skills transfer **46.7%**
Assisted co-management from knowledgeable 3rd parties or previous owners	1	6.7%	
Proper skills gap analysis of beneficiaries	1	6.7%	
Individual ownership – transfer of title	2	13.3%	Finance and ownership **53.3%**
Access to capital and working capital finance	6	40.0%	
TOTAL	**15**	**100.0%**	

The reasons why the measures in Table 4 were not implemented or considered are summarised in Table 5. The most common reason cited was naivety and ignorance from Government and other parties involved to assume that these farms will continue as in the past without further intervention or support at 62.5%.

Table 5: Reasons for not considering the listed action items.

Why were the action items not considered?	**Number of times cited**	**%**
Naivety and ignorance of the Government and other parties involved	5	62.5%
No ongoing support to ensure farms remain commercially viable	2	25.0%
Previous owners saw opportunity to sell farm at inflated prices due to pressure on land reform	1	12.5%
TOTAL	**8**	**100.0%**

Table 6 summarizes the major reasons why land reform was not successful in the past. The table compares the Venezuelan and Zimbabwean case studies, the High-Level Panel and Advisory Panel findings, the current public perceptions on the Expropriation Bill as well as the responses received from the questionnaires.

Table 6: Major reasons for land reform failures.

Items	Venezuela	Zimbabwe	High Level Panel	Advisory Panel	Public perception of Bill	Questionnaire	Total
Full titles were not given to beneficiaries	✓	✓	✓	✓	✓	✓	**6**
No access to capital and finance	–	✓	✓	–	✓	✓	**4**
Political agendas, interference and corruption	✓	✓	✓	–	✓	–	**4**
No legal protection	✓	✓	–	–	–	–	**2**
Food production reduced because of the lack of post-reform support including mentorship programmes	✓	✓	✓	✓	✓	✓	**6**

In all cases are full ownership of land and post reform support the major components that are necessary for a successful land reform program. Access to finance and capital are linked to the above and will be addressed to a large extent if these major two aspects are successfully addressed and implemented. Political agendas and corruption also play major roles and will have to be eliminated. Legal protection by the law and a robust legal system to keep the process of land reform honest goes hand in hand with this.

Although there will always be challenges to land reform, from financial to social, it is clear that no land reform program will be successful if these aspects are not addressed first.

The majority of the participants (58.8%) indicated that land expropriation with compensation will have a negative effect on the ability of South Africa to provide in its demand for food. The major reasons cited for the decline in food production are again the lack of technical, financial and operational support post land reform, the lack of commercial farming skills of the beneficiaries and no training and mentorship.

The opinion of the participants if EWC will have a different effect on food production than expropriation with compensation were tested. Most of the participants (58.8%) indicated that EWC will have a more negative effect on food production, followed by 41.2% indicating the effect will be the same and none saying it will have a more positive effect.

The major reasons cited for a more negative effect are that the current owners will not be motivated to continue investing in the farms to ensure optimal productivity levels as well as that expropriation would be fast tracked, thereby increasing the number of expropriations and reduce the food production capacity of these farms. The reasons why some feel EWC will have the same effect as with compensation are firstly, it will affect the individual balance sheets of the current owners and not necessarily food production. Secondly, is that many foods can be imported at the same price if not cheaper. This argument might be true in a normal inflationary environment, but if expropriation leads to hyper-inflation as in Venezuela and Zimbabwe, the importation of food will be much more expensive. Thirdly, only unproductive land will be expropriated and thus will not have a material effect on current food production, the same as for expropriation with compensation. Assuming that expropriation, with or without compensation, will have a negative effect on food inflation, the participants were asked their reasons on the effect it will have on the overall food inflation of South Africa. Most of the participants (70.6%) indicated that food will have to be imported and with the weakening of the ZAR these imports will be more expensive.

The participants were asked which agricultural produce will be affected the most by land expropriation. The results were mixed and no definitive conclusion could be made.

Lastly, the participants were tested on their knowledge of the current Land Expropriation Bill and more specifically, if they knew the five circumstances in which land can be expropriated without compensation. The aim is to establish if these opinions and feedback were based on perceptions, media opinions or the actual circumstances as listed in the proposed Bill.

Almost 59% of the participants knew the five conditions for EWC. However, only 17.6% of these participants could list the five conditions correctly while the majority, (35.3%) could not list them at all. This, with the 41% of participants that do not know the circumstances at all, it is safe to say that the general knowledge of the Land Expropriation Bill is lacking and much of the current debate is driven by emotions, perceptions and the view that the process will not be transparent and cannot be trusted. This is understandable since the legacy of the Zimbabwean land reform process is close to home and the impact can still be seen today.

7 CONCLUSION

Most of the participants are of the opinion that land expropriation with or without compensation will have a negative effect on the ability of South Africa to produce food for

its local demand and will lead to increased food inflation, because food will have to be imported and with a weakening exchange rate will lead to higher prices. They also are of the opinion that EWC will have a larger negative effect than expropriation with compensation. These opinions correlate with the literature review and the Zimbabwean and Venezuelan case studies.

All the agricultural sub-sectors will be negatively impacted to some degree, but wheat and maize will be impacted the most. These sub-sectors are also the staple food of the South African population and will have a definite negative effect on food security and food inflation. This in turn can lead to social unrest as have been seen in the past.

Post land reform support, skills transfer, mentorship, transfer of ownership and access to finance are the major factors listed for a successful land reform programme. These factors might seem simple in the face of it but will require a large amount of commitment and willingness from all parties involved. These include the current owners, agricultural businesses, large retailers, food manufacturers, financial institutions, the State and the beneficiaries of the land.

It further seems the current sensitivities on EWC are based to a large extend on public perception and media sensationalism and the general population does not know the detail for EWC listed in the Bill.

Land reform is a given and is necessary for South Africa. However, it is clear that the execution thereof requires a far more considered approach in which post land reform support outweighs any other factors.

REFERENCES

[1] van Zyl, B., Farming holds its own in South Africa: Productive farms should not be tampered with. http://www.harvestsa.co.za/articles/farming-holds-its-own-in-south-africa-24809.html#targetText=There%20are%20around%2035%20000,commercial%20farmers%20in%20South%20Africa. Accessed on: 7 Sep. 2019.

[2] Kirsten, J. & Sihlobo, W., Agriculture and land reform: How far are we from an integrated and inclusive rural economy? https://www.businesslive.co.za/bd/opinion/2021-04-07-agriculture-and-land-reform-how-far-are-we-from-an-integrated-and-inclusive-rural-economy/. Accessed on: 10 Apr. 2021.

[3] StatsSA, Census of commercial agriculture, 2017. Financial and production statistics. Pretoria: Department: Statistics South Africa, 2020.

[4] von Bormann, T., *Agri-Food Systems: Facts and Futures – How South Africa Can Produce 50% More by 2050*, World Wide Fund for Nature: Cape Town, 2019.

[5] StatsSA, Mid-year population estimates, 2019. Statistical release P0302, 2019. Statistics South Africa: Pretoria.

[6] Uys, G., Threats to commercial farms. https://www.farmersweekly.co.za/opinion/by-invitation/threats-to-commercial-farms/. Accessed on: 2 Sep. 2019.

[7] Gosling, M. & Moolla, Y., South Africa's ever-shrinking farmers. https://www.iol.co.za/mercury/south-africas-ever-shrinking-farmers-1167943. Accessed on: 6 Sep. 2019.

[8] Joubert, L., Supermarkets changing food relationships. http://southafrica.co.za/supermarkets-changing-food-relationships.html. Accessed on: 2 Sep. 2019.

[9] Picknpay.com, Integrated annual report, 2021 for the 52 weeks ended 28 February. Pick 'n' Pay Stores Limited: Cape Town.

[10] Export.gov, South Africa: Agricultural sector. https://www.export.gov/article?id=South-Africa-agricultural-equipment. Accessed on: 27 Aug. 2019.

[11] Shisana, O. et al., *The South African National Health and Nutrition Examination Survey*, HSRC Press: Cape Town, 2014.
[12] Temple, N. & Steyn, N.P., The cost of a healthy diet: A South African perspective. *Nutrition*, **27**(5), pp. 505–508, 2011.
[13] Pereira, L.M., *The Future of South Africa's Food System: What is Research Telling Us?* Southern Africa Food Lab: South Africa, 2014.
[14] Rahmanian, N., Comparing agricultural trade dependency and household food expenditure in South Africa. University of Pretoria: Pretoria, 2015.
[15] The Global Economy.com, South Africa: GDP share of agriculture. https://www.theglobaleconomy.com/South-Africa/share_of_agriculture/#:~:text=South%20Africa%3A%20Value%20added%20in%20the%20agricultural%20sector%20as%20percent%20of%20GDP&text=The%20average%20value%20for%20South,from%202019%20is%201.88%20percent. Accessed on: 28 Jan. 2020.
[16] Lakmidas, S., Analysis: South African mining grapples with decline of union NUM. https://www.reuters.com/article/us-safrica-mining/analysis-south-african-mining-grapples-with-decline-of-union-num-idUSBRE8AF1AJ20121116. Accessed on: 28 Jan. 2020.
[17] Bam-Yam, Y., Lagi, M. & Bar-Yam, Y., South African Riots: Repercussion of the global food crises and US drought. https://arxiv.org/pdf/1307.5268.pdf. Accessed on: 18 Dec. 2018.
[18] Corcoran, B., South African farm workers clash with police in wages protest. https://www.irishtimes.com/news/s-african-farm-workers-clash-with-police-in-wages-protest-1.552507. Accessed on: 18 Dec. 2018.
[19] Louw, M., An economic analysis of food inflation in South Africa. Pretoria, 2017.
[20] Lagi, M., Bertrand, K.Z. & Bar-Yam, Y., *The Food Crises and Political Instability in North Africa and the Middle East*, Cambridge, 2011.
[21] Mohanty, M.S. & Klau, M., What determines inflation in emerging market economies? *BIS Papers*, **8**, pp. 1–38, 2001.
[22] SARB, Quarterly Bulletin – March 2020, SARB: Pretoria, 2020.
[23] MarketLine, Food and grocery retail in South Africa. www.marketline.com.
[24] Coetzee, J., Key take-aways of the Expropriation Bill, 2020. https://www.lexology.com/library/detail.aspx?g=e8fbe5ed-cc8c-4ae5-91f9-5762716b35e3. Accessed on: 19 Mar. 2021.
[25] Boshoff, T., Sihlobo, W. & Kirsten, J., Expropriation Bill still keeps expropriation as a last resort. https://www.businesslive.co.za/bd/opinion/2020-10-17-expropriation-bill-still-keeps-expropriation-as-a-last-resort/. Accessed on: 8 Apr. 2021.
[26] Advisory Panel on Land Reform and Agriculture, South African Government, 4 May 2019. https://www.gov.za/sites/default/files/gcis_document/201907/panelreportlandreform_0.pdf. Accessed on: 14 Nov. 2020.
[27] RSA, Report of the High Level Panel on the assessment of key legislation and the acceleration of fundamental change. https://www.parliament.gov.za/storage/app/media/Pages/2017/october/High_Level_Panel/HLP_Report/HLP_report.pdf. Accessed on: 30 Sep. 2020.
[28] Hlomendlini, H. & Makgolane, P., Land expropriation without compensation: Possible impact on the South African agricultural economy. https://www.bizcommunity.com/Article/196/358/165375.html. Accessed on: 10 Sep. 2019.

[29] Free State Agriculture, Expropriation will NOT speed up land reform, says FSA. https://vrystaatlandbou.co.za/expropriation-will-not-speed-up-land-reform-says-fsaonteiening-sal-nie-grondhervorming-versnel-nie-vrystaat-landbou/. Accessed on: 4 Mar. 2021.
[30] Merten, M., Expropriation Bill not just about land, but all property, divergent groups warm MPs. https://www.dailymaverick.co.za/article/2021-03-24-expropriation-bill-not-just-about-land-but-all-property-divergent-groups-warn-mps/#:~:text=%E2%80%9CExpropriation%20is%20not%20restricted%20to,hearings%.20on%20the%20Expropriation%20Bill. Accessed on: 8 Apr. 2021.
[31] Mabasa, B., interview by Bruce Whitefield, The Land Expropriation Bill: What you need to know. The Money Show. Primedia (Pty) Ltd. https://omny.fm/shows/the-money-show/the-land-expropriation-bill-what-you-need-to-know. Accessed on: 8 Apr. 2021.
[32] Braun, V. & Clarke, V., *Successful Qualitative Research: A Practical Guide for Beginners*, SAGE: London, 2013.

CURRENT SITUATION OF STAKEHOLDERS' CHARACTERISTICS IN CHU-MANGO SUPPLY CHAIN

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ABSTRACT
The paper approached value chain analysis methodology to identify the flow of information and activities between direct and indirect actors at every channel in the supply chain. A simple random technique was used to select 750 sampling observations for the Chu-mango value analysis. The findings indicated 71% of farmers sell their products to collectors, and 18.8% of mango volume is sold to wholesalers. A further 9.2% sell to cooperatives, and a tiny minority (1%) is sold to local retailers. The main role of cooperative and farmer group share farming techniques is to control agrochemical use in the production process of VietGAP, GlobalGAP, traceability code, and providing information on market opportunities to members. Most of collector transacts with farmers and wholesalers are not contractual agreements that are based on a good business relationship and a responsibility to comply with the supply. Wholesaler is pivotal trader in both the output and input partners of actors in the value chain at the regional and national levels. The wholesaler also plays the role of a fresh mango exporter to the Chinese market. The transaction takes place in cash for channel 2, bank transfer for channel 3, and both for channel 4. Processing firms play an essential role in the consumption of Chu-mango grades 3 and 4 of farmers and create value-added products for consumers. However, the percentage of Chu-mango in exporting enterprises only accounts for a modest proportion of companies' business operations. Most of fresh mango export enterprises must invest in cool sorting systems, packing factories, and vapor heat treatment factories to ensure the tested fresh fruit before exporting. markets for mango are very promising when Vietnam joins trade agreements such as comprehensive and progressive agreement for the trans-Pacific partnership (CPTPP), the European Union Vietnam free trade agreement (EVFTA), and the Asean economic community (AEC). Most import taxes of partners are zero for Vietnamese mangoes and mango products.
Keywords: current, channel, stakeholder, characteristics.

1 INTRODUCTION

Agri-supply chains are economic systems that distribute benefits and apportion risks among participants. Thus, supply chains enforce internal mechanisms and develop chain-wide incentives to ensure the timely performance of production and delivery commitments. They are linked and interconnected by virtue of shared information and reciprocal scheduling, product quality assurances, and transaction volume commitments.

In agriculture, value chain analysis (VCA) implies managing the relationships between the businesses responsible for the efficient production and supply of products from the farm level to consumers to meet consumers' requirements reliably in terms of quantity, quality, and price. In practice, this often includes the management of both horizontal and vertical alliances and the relationships and processes between firms. Another highlight aspect of the value chain is rural–urban linkages that are crucial to the living conditions of people in rural areas.

Mango has emerged as a major fruit for domestic consumption and international export. Chu-mango is a well-known variety in the local and foreign markets. Although there are many varieties of mango in the Mekong Delta (MD), Hoaloc-mango and Chu-mango are two delicious mango varieties that are widely known consumers. Chu-mango has an elongated


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shape, an average weight of 300 to 450 g a sweet taste, lots of water, thick flesh, yellow color, and pleasant aroma. Chu-mango is an important fruit in Vietnam and is popularly used as a vitamin supply source. It is not only used as fresh fruits but can also be used in processing products as well. According to Laura [1] the main stakeholders of the mango value chain are growers, cooperatives, middlemen, wholesalers, processing companies, retailers, exporters, and final consumers. Main purpose of the study provides an overview of stakeholders' characteristics and discusses the importance of each actor' characteristics in Chu-mango supply chain in MD. Finally, the paper presents the author's conclusions derived from the performed research.

2 MATERIALS AND METHODS

2.1 Data collection

Data collection was carried out in multiple stages. First, we discussed agricultural extension workers at the province level (four discussion groups, four people/group), and district level (four discussion groups, four people/group) to choose mango villages for investigation. Second, the study had four discussion groups of farmers (six people per group) in four provinces to determine the essential factors of mango cultivation before designing the questionnaire. Third, the study conducted a trial survey with 40 sampling observations (10 observations in each province). Finally, a simple random technique was used to select 750 sampling observations for the Chu-mango value analysis (main actors and supporters). In 2018, the study collected 526 sampling observations of farmer actors. In 2019, the study continued to investigate 137 sampling observations, including five cooperatives/farmer groups (in-depth interviews and questionnaires), 30 collectors (questionnaires), 30 wholesalers (questionnaires), 12 enterprises (in-depth interviews and questionnaires), 45 local retailers (questionnaires) and 15 supermarket/fruit shops (in-depth interviews and questionnaires). In addition, the study collected 31 sampling observations of supporters (16 transporters, 10 agro-input dealers, four central markets, and an agency of phytosanitary inspection 2 for import and export). The process of data collection of all actors in Chu-mango value chain was collected by face-to-face interview. The number of sampling observations of main actors and supporters is illustrated in Table 1.

2.2 Conceptual framework

Nowadays, the concept of collective economics reflects the collaboration and alliances of stakeholders to become increasingly popular. It refers to the relationship between input providers, producers, collectors, distributors, wholesalers, retailers, and final customers. It focuses on the linkage between upstream and downstream partners. Hence, it is called a supply chain [2]. Bozarth and Handfield [3] contend that supply chain efficiency can be obtained through the active management of all business activities within the supply chain. The management of product, information, and finance flows plays an important role in maintaining minimum costs and profitability as much as possible (supply chain management). Traditional marketing is a model of customer orientation. Customers play a key role in their business strategies.

In contemporary conditions, different concepts of cooperation and correlations between economic operators have been developed. This is called a supply chain. They refer to entire economic flows, from the raw material producer, across all levels of production and

Table 1: The number of sampling observations.

	Observations	Data collection	Year
Main actors	**663**		
1. Farmer - An Giang: 78 - Tien Giang: 98 - Vinh Long: 150 - Dong Thap: 200	526	Questionnaire	2018
2. Cooperative/farmer group	5	In-depth interview Questionnaire	2019
3. Collector	30	Questionnaire	2019
4. Wholesaler	30	Questionnaire	2019
5. Local retailer	45	Questionnaire	2019
6. Enterprise	12	In-depth interview Questionnaire	2019
7. Supermarket, fruit shop	15	Questionnaire	2019
Supporters	**87**		
Agricultural department, center for trade promotion (provincial level)	16 (4 staffs/group)	Group discussion	2018
Local authorities (district, commune level)	16 (4 staffs/group)	Group discussion	2018
Farmer group (community level)	24 (6 farmers/group)	Group discussion	2018
Transporter	16	In-depth interview	2019
Agro-input dealers	10	In-depth interview	2019
Central market of fruit and food	4	In-depth interview	2019
Agency of Phytosanitary Inspection 2	1	In-depth interview	2019
Total	**750**		

distribution and finally to consumption. This means that relationships need to be built not only with clients but also with key suppliers and middlemen when producing and delivering goods or services. It consists of both upstream and downstream partners. Suppliers, intermediaries, and intermediaries' clients are included and delivery value networks are created for customers and other stakeholders to achieve a sustainable competitive advantage [4].

> "Supply chain management (SCM) is the integrated planning, implementation, coordination, and control of all business processes and activities necessary to produce and deliver, as efficiently as possible, products that satisfy market requirements" [5].

The marketing channel is defined as the expansion of SCM to understand the demands of each client and segment in every specific channel [6]. This creates delivery value networks, not only vertical alliance stakeholders, but also horizontal collaboration of the same agents.

In this study, approach methodology is applied to determine relationships and how actors interact and transact with each other (Fig. 1). This way shows the flow of information and activities between direct and indirect actors at every channel in the supply chain. It helps to illustrate characteristics of stakeholders. Descriptive statistics were used to describe the characteristics of main actor of Chu-mango distribution system, calculate value percentage of each actor of mapping in value chain. The descriptive statistics are presented in tables by using frequency, percentage, mean, standard deviation [8]–[11].

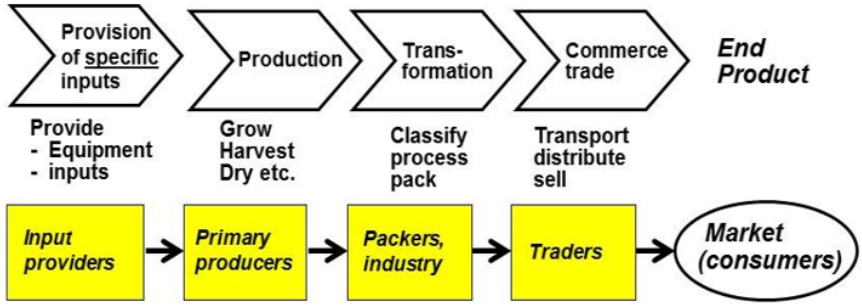

Figure 1: Supply chain map [7].

3 RESULTS AND DISCUSSION

The Chu-mango value chain map illustrates how Chu-mango products are contributed via various marketing channels from farms in the MD region to domestic and foreign consumers. The diagram shows that several actors participated in the flow of the Chu-mango supply chain. The percentage of marketing channels is the share of Chu-mango volume produced by responding growers with a total volume of Chu mango in the MD region of approximately 115,700 tons.

The distribution system of the Chu-mango value chain includes two main channels. The export channels (marketing channels 1, 2, and 3) and domestic channels (marketing channels 4 and 5).

Channel 1	Farmer	→ Cooperative	→ Export Enterprise			
Channel 2	Farmer	→ Cooperative	→ Wholesaler	→ Processing Firm		
Channel 3	Farmer	→ Collector	→ Wholesaler (China)			
Channel 4	Farmer	→ Collector	→ Wholesaler	→ Supermarket		
Channel 5	Farmer	→ Collector	→ Local retailer			

3.1 Chu-mango farmers' characteristics

Table 2 provides more detailed information about the characteristics of mango households in the MD. The vast majority of household heads (94.8%) were male, while a very small number (5.2%) were female. Based on different age groups of household heads, the maximum range is the age group of above 56 years (40.1%), followed by the age group of 46–55 years, 35.2%). The minimum range is the age group under 30 years (0.7%). In general, mango farming does not attract young people in rural areas. For the educational levels of farmers, the maximum level of the farmers was secondary school (45.3%), followed by primary school

(approximately one in three). The level of high school is about a fifth, while a small number is college level (2.2%). In general, farming experience of the household head focuses on the group over 10 years, accounting for nearly 80%. This allows growers to build suitable farming plans based on their experiences in regularly extreme weather and climate change circumstances that directly affect mango production efficiency.

Table 2: Demographic profile of farmer. *(Source: Field Survey Data, 2018.)*

Demographic variables	**Frequency N = 267**	**Percentage %**
Gender distribution		
Male	253	94.8
Female	14	5.2
Age distribution		
≤ 30 years	2	0.7
31–45 years	64	24.0
46–55 years	94	35.2
≥ 56 years	107	40.1
Educational status		
Primary school	85	31.8
Secondary school	121	45.3
High school	55	20.6
College/university	6	2.2
Farming experience		
≤ 5 years	9	3.4
6–10 years	50	18.7
11–15 years	55	20.6
16–20 years	105	39.3
>20 years	48	18.0
Mango area		
< 0.2 ha	13	4.9
0.2–0.5 ha	132	49.4
0.51–0.7 ha	52	19.5
0.7–1.0 ha	42	15.7
> 1.0 ha	28	10.5
Density		
≤ 200 mango trees/ha	207	77.5
201–350 mango trees/ha	44	16.5
> 350 mango trees/ha	16	6.0
Farming type		
Intensive farming (only Chu-mango)	213	79.8
Intercropping with other fruits	54	20.2
Credit (loan)		
Yes	44	16.5
No	223	83.5

The results in Table 2 indicate that most mango growers are smallholders. For example, the group of less than 0.51 ha is the highest percentage in all groups, occupying 54.3%, followed by the 0.51–0.7 ha group at around a fifth and 0.71–1.0 ha group at 15.7%. Only 10.5% consists of a group of over 1.0 ha. In addition, 77.5% of growers' design orchards with a density of approximately 200 mango trees per hectare under irrigation through water channels. Noticeably, a significant proportion 79.8% of growers chose intensive farming type compared to only 20.2% of growers selected intercropping with other fruits.

Regarding credit access, 83.5% of respondents did not borrow from credit organizations. In fact, farmers· main purpose access credit to purchase agro-inputs for the next crop. At the same time, agro-input dealers allow growers to get agro-inputs serving production, and payment takes place in ending crops with an interest rate of 1.2–2.0%/month. Thus, their credit demand in production is significantly reduced. In addition, 16.5% of growers borrowed from the Vietnamese Bank for Agriculture and Rural Development, and the Vietnam Bank for Social Policies, with an interest rate of 1.0% per month. This credit is used to buy fertilizers, pesticides, production tools, and hired labor costs.

Mango farmers, who are key actors in the mango supply chain, are the weakest links in the chain system. The given map of the Chu-mango value chain (Fig. 2) shows that 71% of farmers sell their products to collectors, and 18.8% of mango volume is sold to wholesalers. A further 9.2% sell to cooperatives, and a tiny minority 1% is sold to local retailers. At present, most farmers have applied off-season flowering stimulation techniques to spread production around the year and avoid the occurrence of seasonal glut harvest and falling sale prices. The main activities of mango cultivation include pruning and creating a canopy, irrigating, fertilizing, spraying pesticides, wrapping fruit, and harvesting. These activities are carried out by family and hired labor. There are professional teams in locals that meet the requirements of all farming techniques from mango gardeners. Harvesting is decided by the household head based on the fruit color and size, as well as the mature fruit from the trees,

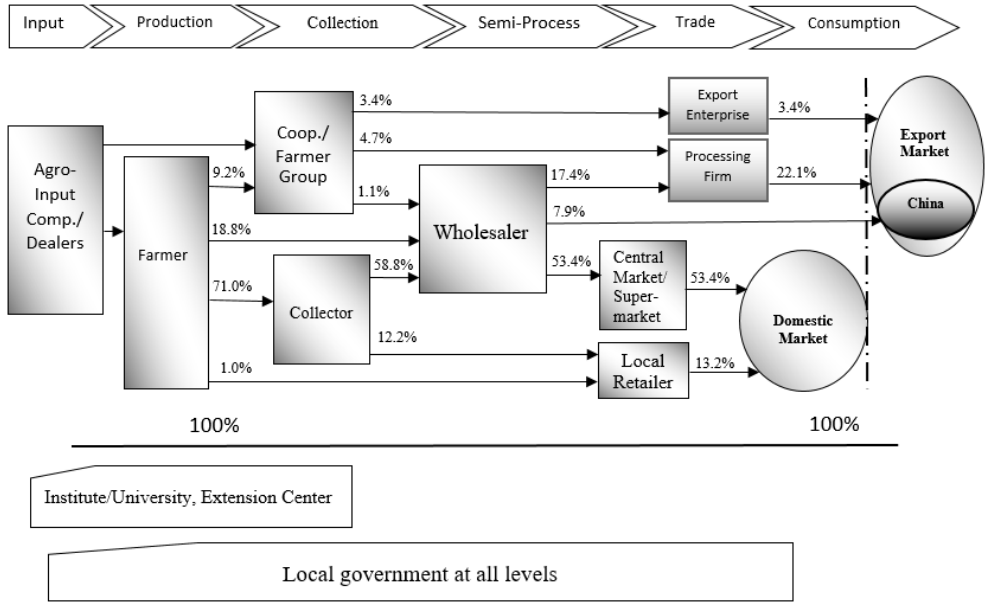

Figure 2: Distribution system of Chu-mango in the Mekong Delta.

harvested by using sticks with a hook and small bag attached to the end. Mango is often harvested in the morning and packed by households in bamboo and plastic baskets, padded with paper. Farmers can sell their mangoes at the orchard or transport some of their mangoes themselves to collectors and wholesalers by motorbikes or small lorries. Mangoes are sold immediately on the same day that they are harvested.

Mango cultivation is a small-scale farmer. It is illustrated in Table 3 with average farm size approximately 0.4 ha. Although the mango farming area is small-scale, the MD is considered a mango production center in Vietnam due to favorable conditions such as soil, water source, and tropical climate. Mango productivity in the MD region is the highest in all regions, especially Chu-mango, with over 10 tons/season.

Table 3: Area, productivity, and selling price of Chu-mango growers. *(Source: Field Survey Data, 2018.)*

Seasons	Area (ha)	Productivity (ton/ha)	Selling price (USD/ton)			
			Normal	Grade 2	Grade 3	Grade 4
Season 1	0.39	11.21	786.32	987.66	494.69	260.71
Season 2	0.41	10.32	779.09	1,023.18	526.35	256.52
Season 3	0.45	10.66	615.57	915.11	508.85	244.74

Overall, the selling price of Chu-mango in the off-season (seasons 1 and 2) was higher than that of the natural season (season 3). Growers can choose two ways to sell their mangoes, either normal mango (non-classification) or mango classified. At the household level, Chu-mango is usually divided into three grades (grades 2, 3, and 4, with rates of 58%, 35%, and 7%, respectively). Growers usually sell classifying types when they estimate their mangoes to obtain over 60% of grade 2. This brings about a selling price better than the normal mango type (non-classification). At the export enterprise and wholesaler level, Chu-mango grade 2 continues to be classified as grade 1, with a rate of 40% of grade 1. Mango grade 1 must meet the sanitary and phytosanitary requirements of importers with both extrinsic and intrinsic attribute indicators. In this case, the household level does not have sufficient professional capacity to classify. In short, the normal Chu-mango is divided into four grades comprising: 23% of grade 1, 35% of grade 2, 35% of grade 3, and 7% of grade 4.

3.2 Chu-mango cooperatives' characteristics

Cooperative and farmer groups play an important role in linking chains among farmer-cooperative companies. It is considered a bridge between mango growers and export enterprises. The main role of cooperative and farmer groups is to implement and monitor mango farming processes to achieve grade 1 mango exports. These cooperative and farmer groups usually evaluate farmers' farming processes by diary and field tests. In addition, members of the cooperative and farmer groups are trained and shared mango cultivation techniques such as tree-pruning techniques, efficient agrochemical application, flowering stimulation, and fruit wrapping towards safe and high-quality products to meet market requirements.

Importantly, cooperative and farmer groups that have received support both finance and technique from the provincial government or non-government to cover the costs of GlobalGAP, VietGAP certification, and traceability code. This is one of the crucial factors to appeal to exporting companies to establish linkages with cooperative and farmer groups. For example, the total mango area of VietGAP certification is 320.41 ha from nine

cooperatives and 31 farmer groups in Dong Thap province, and this number in Vinh Long province is 87.69 ha mango with VietGAP certification from three cooperatives and 22 ha GlobalGAP certification of Quoi An cooperative. However, the validity of these certifications only ranges from two to four years. Thus, the renewal or re-certification cost of GAP certification is a challenge for cooperative and farmer groups. It is very expensive (USD 9,000 for new certified costs and USD 6,000 for re-certification of about 15–25 ha), while funds from local government and NGOs for this activity are limited.

In other aspects, cooperative and farmer groups still cultivate mango orchards following the process of GlobalGAP and VietGAP without certification. Alternatively, they get traceability code with cheaper cost (1,000 USD/code) and are responsible for sanitary and phytosanitary standards with partner enterprises. The total area of the traceability code of Chu-mango was over 500 ha in the study area. This is the result of collaboration between cooperative and farmer groups and companies from production to consumption toward advanced markets in the world.

The main role of cooperative and farmer group share farming techniques is to control agrochemical use in the production process of VietGAP, GlobalGAP, traceability code, and providing information on market opportunities to members. Moreover, cooperative and farmer groups are often supported by VietGAP, GlobalGAP, and traceability code certification costs by local government and non-government organizations (NGOs. They are trained farming technique by extension center and agro-input companies. It is given priority to become input suppliers for export enterprises. One of the main purposes of participating in cooperative and farmer groups is to establish a strong horizon linkage. In fact, the role of cooperatives in the value chain is as a collector rather than a business organization. However, cooperatives face several challenges such as lack of capital, market access, governance capacity, technology (production, semi-processing, storage, etc.), professional labor, and negotiation and business skills, etc. Lack of trust between cooperative members and the management board, between cooperative with company. Big differences in selling price agreements, in share on information, benefits, and risks. To be more effective, the cooperative needs to restructure the operational organization, boost governance capacity, increase negotiation and business skills, attract young staff (who may apply new technology, e-commerce, etc.), and collect capital in production and investment. This requires stronger support from both the Vietnamese government and NGOs to improve cooperatives' capacity in the long term.

3.3 Collector's characteristics

A collector, a small trader, purchases mangoes from growers. They are important actors in the Chu-mango value chain. They help small-scale farmers connect to the market. In particular, the remote places that are rural transport have poor access to the market. The main vehicles for mango delivery of collectors are motorbikes and minivans (300 kg to 1.2 tons) depending on the local infrastructure. Approximately 71% of growers' mango volumes are distributed by collectors. They either buy farmers' mangoes after harvest (harvesting farmers), or purchase fruit-bearing trees (harvesting collector). Usually, the collector visits mango orchards three to seven days before the harvest to inspect fruit quality from a few trees and set up the price. They then sell to wholesalers (58.8%) in the central markets of the MD region (My Hiep, An Huu) and Ho Chi Minh City (Hoc Mon, Binh Dien, Thu Duc), who in turn sell to retailers (12.2%) in local markets in the MD. Most of their transactions with farmers and wholesalers are not contractual agreements that are based on a good business relationship and a responsibility to comply with the supply. All payments for merchandise

are carried out in cash. Price decisions are based on the extrinsic attributes of mango, such as fruit size, maturity, color, weight, etc., rather than the quality measurement of intrinsic attributes and agrochemical residues.

3.4 Wholesaler's characteristics

At present, the wholesaler plays the backbone role of the Chu-mango supply chain, with 78.7% of the total mango volume. They are pivotal traders in both the output and input partners of actors in the value chain at the regional and national levels. They purchase approximately 1.1%, 18.8%, and 53.4% of mango volume from the cooperative, farmer, and collector, respectively, while they also provide 17.4%, 7.9%, and 53.4% of mango volume to the processor, Chinese market, and central market and supermarket, respectively (Fig. 2). The wholesaler also plays the role of a fresh mango exporter to the Chinese market in marketing channel 3. My Hiep and An Huu are two of the biggest central markets of fruit in the MD, which have over 200 fruit wholesalers within a 20 km radius. Here, mangoes are delivered to domestic consumers and the Chinese market. The transaction takes place in cash for channel 2, bank transfer for channel 3, and both for channel 4. All mangoes are classified before selling, mango grades 3 and 4 for channel 2, and mango grade 2 for channels 3 and 4.

Trucks are the main vehicles transporting mangoes to the central market and China. If the journey goes to Dang Nang, Ha Noi, and China, heavy trucks will be installed in a cooling system with an electronic chip to control the temperature. In the MD, produce takes 3 h to reach Ho Chi Minh city, 16–18 hours to Da Nag city (the middle of Vietnam), 48–52 hours to Ha Noi city (the north of Vietnam), and 60–72 hours to border gate between Vietnam and China. In channel 3, transactions take place either in Vietnamese territory or in the Chinese domain. If it is transacted in the Chinese domain, the charge of custom cost will be 260–350 USD/container (25–30 tons).

3.5 Retail system characteristics

The retail system is divided into two levels: large-scale retailers in big cities (channel 4) and local retailers (channel 5).

Local retailers are small-scale sellers and buy directly from collectors (12.2%) and farmers (1.0%) who bring mangoes to their retailing point. They purchase normal Chu-mango (non-classification), after which they classify it into grades 2, 3, and 4 before selling to consumers. In this way, they ensure better profits from a higher selling price. Merchant activities occur in open-air markets and street vendors. The local retailer usually merchandizes daily from to 15–50 mangoes kg/day (after 3 to 5 days without a cooling system). In addition, they also sell diverse tropical fruits. The fruit loss for the local retailer is high about 15–20%, stems from anthracnose, over-ripe fruit, and transportation damage.

For the large-scale retailer, this is the leading trader of the supply chain; approximately 53.4% of the Chu-mango volume is provided to the domestic market via this actor. Mango must be classified as grade 2 at the wholesaler before transporting it to them. Chu-mango in channel 4 meets the requirements of certification of GlobalGAP or VietGAP, traceability code, and without a banned list of pesticides. Its distributed systems are mainly fruit malls (Vinmart plus, Tuong Vy, South Fruit, Klever fruit, Fruitstore, NQ fruit), supermarkets (Coopmart, Lotte, Big C, Mega market, AEON, Bach Hoa Xanh, etc.), and central markets in big cities (Hoc Mon, Thu Duc, and Binh Dien in HCM city, Hoa Cuong in Da Nang city, Long Bien in Ha Noi city). There is a difference in the selling volume of Chu-mango fruits between supermarkets/malls and the central markets. More specifically, the supermarkets or

malls are around 100 to 350 kg per day, and the central markets are about 200 to 600 kg per day. We thank the wholesaler for careful classification that the fruit loss is about 5 to10% by over-ripe fruit and transportation damage. Maintaining Chu-mango on the fruit shelf in the mall or supermarket is 12 to 20 days with a cooling system, while it is only 5 to 10 days in the central markets without a cooling system.

3.6 The characteristics of export enterprise and processing firm

The study carried out a survey of 12 export companies. In general, export companies transact many kinds of fruits and vegetables, and the scale of these companies in Vietnam is mainly small and medium enterprises (SMEs), in which most processing companies are medium-scale, exporting companies of fresh fruit are small-scale. Moreover, there are a few enterprises that trade both fresh and processed products**.** The findings indicated that companies exported various varieties of mangoes, of which Chu-mango is the most common variety for exporting fresh and processed products.

The findings of processing firms show the processing firms are medium-scale companies with a large demand for raw fruits and vegetables from 20,000 tons to 120,000 tons per year. Chu-mango is an important input material contribution to the export value of companies. The contribution percentages of raw Chu-mango compared to total raw input materials were 4.6%, 7.1%, 10%, and 20% in Thuan Phong, Hung Phat, Phu Thinh, and Long Uyen companies, respectively. In the Long Uyen Company, Chu-mango is considered the main material source for manufacturing the company. Processing firms play an essential role in the consumption of Chu-mango grades 3 and 4 of farmers and create value-added products for consumers. However, the percentage of Chu-mango in exporting enterprises only accounts for a modest proportion of companies' business operations.

The investigated results of exporting enterprises provide information on the business operations of fresh fruit export enterprises. To meet export requirements, most export enterprises must invest in cool sorting systems, packing factories, and vapor heat treatment factories to ensure the tested fresh fruit before exporting. The scale of these enterprises is small and focuses on exporting dragon fruit rather than other fruits. Its contribution to mango export activities was modest. For instance, the export proportions of Chu-mango are 1%, 2.4%, 3.0%, and 5.0% in the Cattuong, Hoang Phat, Yasaka, and Goodlife companies, respectively.

Overall, exporting fresh fruit often confronts strictly phytosanitary inspection from importing counties as well as control importing quotas. However, markets for mango are very promising when Vietnam joins trade agreements such as comprehensive and progressive agreement for the trans-Pacific partnership (CPTPP), the European Union Vietnam free trade agreement (EVFTA), and the Asean economic community (AEC). Most import taxes of partners are zero for Vietnamese mangoes and mango products.

3.7 Agro-input dealers' characteristics

Mango growers in the MD approach from two providers, one from directly salesmen teams of agrochemical companies, and one from local agro-input dealers. Generally, the input sources of agrochemical dealers are diverse owing to the provision of various companies. At present, agro-input dealers are still the main providers of agrochemicals (pesticides, fungicides, fertilizers) for farmers. Agro-input dealers coordinate regularly to agrochemical companies to organize workshops on how to use appropriate agro-inputs to guarantee successful production crops. In fact, agro-input dealers benefit from both the commission

rate from companies and profit from selling products for farmers. They benefit sales on commission depending on companies' sale policy (Table 4).

Table 4: Commission rate following companies, turnover condition. *(Source: Field Survey Data, 2019 (KIP).)*

No.	Turnover requirement	Commission rate (%)
1	**Small company, turnover each season**	
1.1	4,500–6,500 USD	12.0
1.2	9,000–13,000 USD	15.0
1.3	17,500–22,000 USD	20.0
2.2	**Big company, turnover per year**	
2.1	2.21 million USD	9.0
2.2	4.42 million USD	13.5
3	**Promotion from small company for payment term**	
3.1	07 days	6.0
3.2	30 days	3.0
3.3	60 days	1.5

The results in Table 4 provide information on agrochemical supply sources for agro-input dealers. Overall, agro-input dealers gain commission rates at different levels. The commission from big companies is usually less than that from small companies, while turnover quotas are higher. One of the main causes is that their products are well-known and trade easily. Additionally, big companies are foreign enterprises or companies with strong financial potential, so the payment term is ending year instead of each season as small companies. To be able to compete, small companies must provide a more attractive commission rate and various promotion programs for both dealers and farmers. However, they face the risks of low quality and counterfeit products from small companies. The number of regular customers of agro-input dealers is approximately 150–200 growers who are local and neighborhood farmers. The results indicate that approximately 55% of farmers buy input materials by cash immediately, and 45% of farmers pay in each ending crop with an interest rate of 1.2–2.0% per month. In addition, agro-input dealers are responsible for business tax approximately 100–200 USD/year.

3.8 Transporter's characteristics

Although the transporter is only a supporting actor in the value chain, it contributes vitally to market connections in limited rural transportation conditions. They not only transport agricultural products internal to the MD, but also travel it to spread Vietnam and Chinese bother gates. At present, Vietnam does not yet have a speed railway system to connect the national agricultural products center with other regions of Vietnam. Most fresh fruits and vegetables are transported by trucks on road traffic networks. In this study, 28 drivers were interviewed to collect information on fresh fruit transport, including 16 local divers and 12 drivers for fresh fruit transport to other regions.

In particular, the study conducted an in-depth interview in Mai Truc Company Limited, a popular transport company in Vietnam. The company has a large and powerful truck system with approximately 550 heavy trucks (weight 25–30 tons) for professional transport of agricultural products from the MD to northern Vietnam and Chinese border gates. In the MD, fresh fruit and vegetables take 3 hours to reach Ho Chi Minh city, 16–18 hours to Da Nang

city (the middle Vietnam), 48–52 hours to Ha Noi city (northern Vietnam), and 60–72 hours to the border gate between Vietnam and China. Except for transportation in the southern region, all heavy trucks are installed cooling systems with electronic chips at different temperatures. Every truck has two drivers who get USD 300–350 each driver with a journey of about 5–7 days. If the goods are decomposed by temperature fluctuations, the drivers of the journey will take responsibility for compensation. The company also pays commission for brokers who help find goods for transportation (commission about 8 USD/ton). In addition, the company must pay a BOT fee (build–operate–transfer) of toll stations approximately 350 USD/journey about 30 product tons, and cost for dockers 5.5 USD/ton. Table 5 presents transport charges for fresh fruits and vegetables from the MD to northern Vietnam.

Table 5: Transport charges for fresh fruit and vegetables. *(Source: Field Survey Data, 2019.)*

No.	Type of products	Charge (USD/ton)
1.	Mango, papaya	88.4
2.	Melon, guava, mangosteen	132.6
3.	Citrus, pomelo	150.3
4	Coconut, jackfruit	101.7
5	Durian	154.7
6.	Other fruits	97.3
7.	Vegetables	110.5

4 CONCLUSIONS

The Chu-mango distribution system has eight main actors (farmer, cooperative, collector, wholesaler, export enterprise, processing firm, supermarket/fruit shop, and local retailer) and the five main marketing channels (the three export channels and two domestic channels) to supply to five market segments with different selling prices and quality.

The ending traders of each marketing channel (export enterprise in channel 1, processing firm in channel 2, wholesaler in channel 3, supermarket/shop fruit in channel 4, and local retailer in channel 5) are considered as nuclear actors of revenue growth in the value chain.

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REFERENCES

[1] Laura, O.R., Value chain analysis of mango in Dong Thap province, Vietnam. Opportunities to promote inclusive value chain development. Unpublished Master’s dissertation, Ghent University, Belgium, 2016.

[2] Waters, D., *Logistics: An Introduction to Supply Chain Management*, Palgrave Macmillan: New York, 2003.

[3] Bozarth, C.C. & Handfield, R.B., *Introduction to Operations and Supply Chain Management,* Pearson Education: Upper Saddle River, NJ, 2006.
[4] Mentzer, J.T., *Fundamentals of Supply Chain Management: Twelve Drivers of Competitive Advantage*, SAGE: California, 2004.
[5] Jack, G.A.J., Carlos, A. & Jacques, H.T., *Agro-Industrial Supply Chain Management: Concepts and Applications*, FAO: Rome, Italy, 2007.
[6] Ayers, J.B. & Odegaard, M.A., *Retail Supply Chain Management.* Taylor and Francis: New York, 2008.
[7] Andreas, S.-H., *Valuelinks 2.0 Manual: Manual on sustainable value chain development*, *value chain analysis, strategy and implementation*, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ): Eschborn, Germany, 2018.
[8] Dominic, S., Rodd, D. & Tiago, W., *Making Value Chains Work Better for the Poor: A Toolbook for Practitioners of Value Chain Analysis*, 4th ed., Australian Center for International Agricultural Research: Canberra, 2020.
[9] Douglas, H., Jason, D., André, D. & Maximo, T., Innovation for inclusive value-chain development: Highlights. *Innovation for inclusive value-chain development: Successes and Challenges*, eds D. André, T. Maximo, D. Jason & H. Douglas, International Food Policy Research Institute: Washington, DC, pp. 3–34, 2016.
[10] Trienekens, J., Agricultural value chains in developing countries: A framework for analysis. *International Food and Agribusiness Management Review*, **14**(2), pp. 51–82, 2011.
[11] Kaplinsky, R. & Morris, M., *Handbook for Value Chain Research*, International Development Research Center (IDRC): Ottawa, 2003.

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SECTION 8
CITY/WATERFRONT INTERACTION

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DIGITAL TWIN MODEL FOR ZERO-ENERGY DISTRICTS: THE CASE STUDY OF ANZIO PORT, ITALY

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ABSTRACT

A digital twin (DT) for a built environment is able to predict performances and behaviours across the life cycle through the implementation of predictive models and the real-time monitoring systems. In the present paper, a DT application is described in order to transform port areas in zero-energy districts (ZED) in Italy. The project case study is the port of Anzio, as it is a particularly representative sample of a port in the Mediterranean Sea. The study focuses on energy management strategies for the existing structures integrated with production systems through renewable energy systems (RESs) for sustainable mobility. The energy analysis of the area highlights the potential of DT, combining building information modelling (BIM) and geographic information system (GIS) to evaluate different multi-scale scenarios maximizing benefits of energy efficiency strategies. The proposed DT framework of the Anzio port acquires energy data, presence data, projection of displacements and accesses, among others, together with the data acquired by the distributed sensors allowing elaborations, correlations, scenario simulations and providing insights through dashboards and data visualization.

Keywords: digital twin, renewable energy systems, zero-energy district, digital transformation, BIM.

1 INTRODUCTION

There is a solid and positive relationship between operational efficiency and energy efficiency in port areas, as the increase of energy optimization results in significant energy efficiency. In this regard there is a direct connection between energy and operational efficiency in complex infrastructures such as port areas, as operational efficiency of sources reduces energy consumption [1] as electricity or fossil fuel.

According to policies for air pollution reduction in recent years, the progressive electrification of relevant port areas leads to the integration of renewable energy sources supported by the increasing advances in electricity generation and storage technologies [2]. In addition, a local electric smart grid can be installed to enhance network intelligence and new devices for efficient energy storage using machine learning (ML) to increase energy management.

A smart approach to the monitoring of built environment (e.g., fault detection and diagnostics system using sensor networks and AI-based modern technologies), generates benefits such as reducing maintenance costs, energy consumption and related costs, increased productivity, and extended equipment life [3].

The main objective of the strategy proposed in this paper is the realization of a digital twin (DT) model as a data base able to collect and analyse data coming from sensors, offering a system interface allowing control and monitoring capabilities and enabling predictions about future states [4]. Moreover, the digitization process oriented to digital twin technologies is an opportunity to rethink the approach to urban areas and related infrastructures in a circular economy and sustainability perspective. The proposed framework is intended both for facilitating facilities management operation and for enhancing space management purposes in a sustainable city perspective, according to post COVID-19 pandemics requirements, as occupancy detection is an important part of the facility management to ensure users' safety [5].

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Digital twins (DTs) are virtual replicas of physical assets in operation supporting managers and technicians, enhancing decision-making processes as well as predictive/ adaptive scenarios. DTs are developed as integrated multi-physics, multi-scale, probabilistic simulations, using the best available physical models and sensors to mirror the lifecycle of their real twins [6].

2 MATERIALS AND METHODS

The Regione Lazio project started in 2020, was funded by the department "Mobility Infrastructure and Transport Area" and aimed at developing and enhancing a digital twin model for four different ports, namely, Anzio, Formia, Ventotene and Terracina based on collecting data from different sources through IoT and 5G.

The present research is restricted to the Anzio port (Fig. 1), an area of over 84,022 m^2 characterized by different activities and uses. Its current configuration is the result of a process of urban regeneration that began essentially in 1960 and still continues today because of the design of a new part of the port. In this changing configuration the DT could be the digital platform where the administration can accurately simulate and plan activities in a healthy, safe, comfortable and sustainable way for visitors.

Figure 1: BIM model of the port of Anzio.

In order to design an optimal DT architecture, policymakers (Regione Lazio and Municipality of Anzio) have been involved in order to support their decision-making processes and optimize the port system management. The result of this participate design has been the implementation of a platform, as shown, for instance, in Fig. 2, in order to make available IoT, geo-referenced data, as well as processed and produced data [7].

In fact, the management of the input data coming from different sources, devices and layers for each type of data, will allow the manager to keep under control the performance of the systems, as well as of goods and people flows [4]. Moreover, using energetic simulation tools, it is possible to evaluate different energy-based scenarios coming from an optimization of actual power loads and form the possible integration of renewable energy systems (RES). IoT devices are essential to make every object, person or building a real time data source; and algorithms, through artificial intelligence approaches, make an energy management system more accurate; all the advanced smart sensors are able to collect a large amount of information while data storage is inserted in a common data environment, secure and reliable in Cloud [8], [9].

A prototype has been developed by Sapienza University of Rome for the Lazio region and visualization capabilities were implemented through augmented reality (AR) supporting a

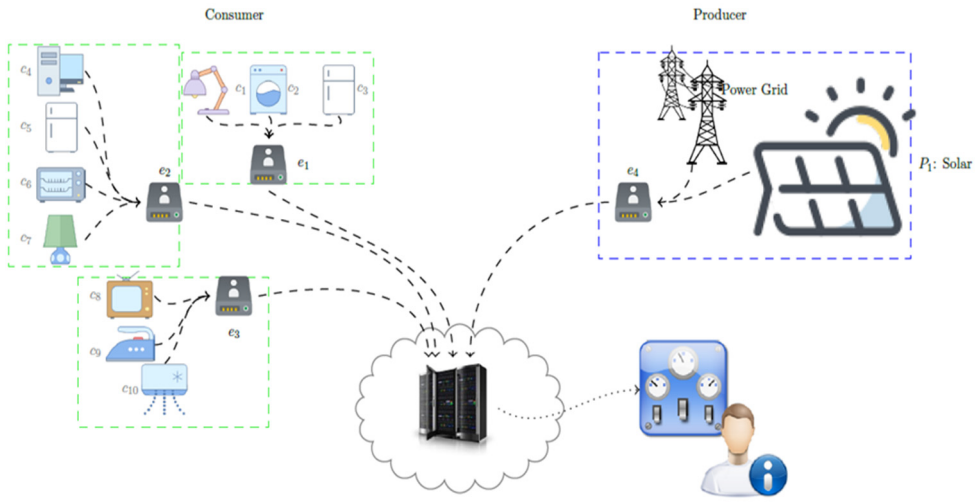

Figure 2: Integrated and multi-layer platform for the port management.

collaborative management approach; starting from a 3D model of the built environment, data are collected from an heterogeneous type of sensors (mobile devices, sensors, video content analysis), and inserted in a multi-layer platform for aggregate data exposure and management.

The collection of data for monitoring are disposed on three main different domains:

- the first one is the installation of smart meters for energy production and consumption, air quality, weather forecasts, sea level, water consumption;
- positioning of security cameras;
- mobile applications receiving from users alerts about faults on the built energy systems with geographical localization.

The inclusion of appropriate shared parameters in the BIM model allows the evaluation of a predictive description of energy consumption associated with the different loads in the port area. The load associated with lighting terminals is about 67% of the total electrical consumption.

In addition, in the north pier area, there are some charging devices for private and public boats. These devices are divided into double charging stations and simple interlocked sockets. The overall electrical consumption of all the devices of the Anzio port area is 90,155 + 129,600 = 219,755 kWh for a year. This is the target of implementing the RESs local grid production in the same place to reach a zero-energy district as described in the result section.

All the data coming from smart meter devices (electrical loads) and an RES production system, such as inverter Fronius, are transmitted by sensors to the platform, and they can be visualized through dashboards able to report and analyse data in real-time as reported in Fig. 3.

3 RESULTS AND DISCUSSION

The realization of a zero-energy district in a port area requires the integration of different RES using available areas. For this project the combination of two different solutions have

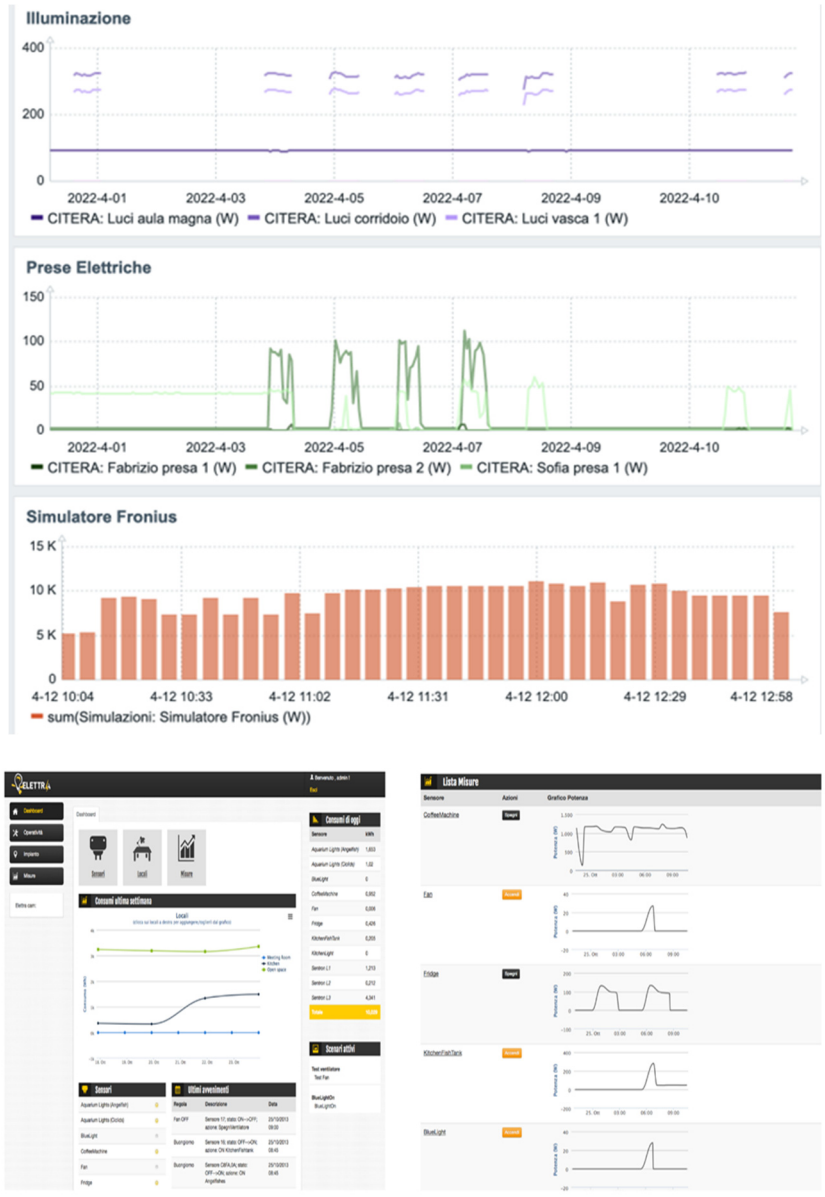

Figure 3: DT energy consumptions: dashboards.

been considered to reach the needed production of 219,755 kWh for a year: photovoltaic panels and micro wind turbines. In fact, the combination of different RES ensures about 40% of energy supply even in unfavourable climate condition. Moreover, wind conditions combined with technical requirements in terms of minimum distance between microturbines did not allow the increase of the supplied wind power, despite the fact that no regulatory

constraints are introduced in the area, as the port is subjected to military harbourmaster authorities.

Fifteen micro wind turbines are located in external port areas, south pier, as shown in Fig. 4; the obtained value from each turbine is approximately 2,420 kWh per year. Therefore, it is possible to produce 36,300 kWh per year with fifteen turbines located in all the free area on the entire north pier.

Figure 4: Pier area for RES installation.

In order to install the photovoltaic modules, the area at the end of the Southern pier was chosen. It is a large area, characterized by good exposure and without shading (there are no buildings nearby), as shown in Fig. 4. As shown in Fig. 5, it is possible to evaluate the area covered by the modules, which is much smaller than the available area, that is, about 2,663 m^2.

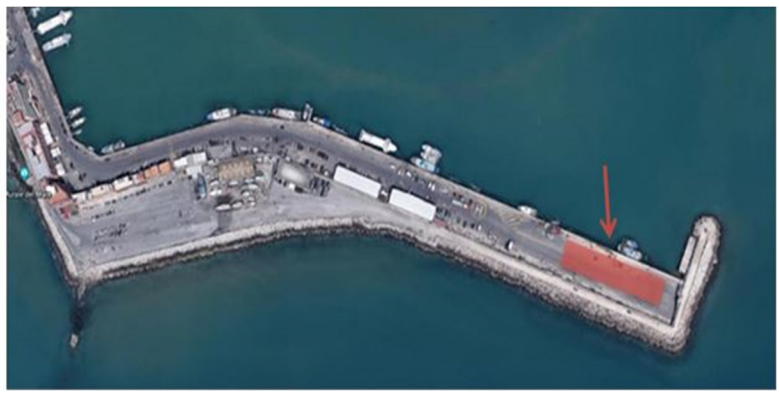

Figure 5: Positioning of photovoltaic models.

The port has a good potential, due to its geometric characteristics and location, and a maximum of two-level buildings is easily transformable into ZEB buildings. A further implementation of the DT and extending the harbour representation can improve its environmental and economic management.

In order to achieve this implementation, the following phases must be considered:

- A primary phase concerns the issue of interoperability between system platforms and languages (middleware) where the system architecture must establish an appropriate shared model for collecting data from the various sources (sensors, inverters, smart meters, etc.).
- The second phase concerns the implementation of smart systems that must be updated and increased over time and always adapted to the changing functionalities required by new operating conditions and/or new emerging technologies.
- Finally, the third phase concerns the correct and adequate installation of connection infrastructures, such as mainly the power supply lines (which must reach every single sensor that needs power) and obviously the network connection (both wired and wi-fi).

4 CONCLUSIONS

The DT of Anzio port project proposes a holistic view of real/virtual spaces acquiring energy data, presence data, projection of displacements and accesses, among others, together with the data acquired by the distributed sensors which allow carrying out elaborations, correlations, scenario simulations that are made available in the dashboards dedicated to the area manager.

The proposed project represents the first phase of a digital transformation process of the coastal cities of the Lazio region, starting from their infrastructural centre. The implications of this transformation directly concern the environmental, economic and social domain, setting the port area as the epicentre and extending to the rest of the city.

Consequently, the digitalization of the area, through this first implementation of the DT for the Port of Anzio, allows the possibility to start from the epicentre of this digital and ecological transformation, to spread throughout the territory, studying the exchange flows with the surrounding territories, linked to transport by sea, land, road and rail [10], [11]. It would also replace economic and environmental costs of electricity production for public lighting and electricity supply to moored boats by switching from carbon to renewable energy sources.

REFERENCES

[1] Wilmsmeier, G. & Spengler, T., Energy consumption and container terminal efficiency. *FAL Bulletin*, **10**, pp. 350–356, 2016. https://www.cepal.org/en/publications/list/date/2016

[2] Parise, G., Parise, L., Malerba, A., Pepe, F.M., Honorati, A. & Ben Chavdarian, P., Comprehensive peak-shaving solutions for port cranes. *IEEE Transactions on Industry Applications*, **53**(3), pp. 1799–1806, 2017. DOI: 10.1109/TIA.2016.2645514.

[3] Brunone, B., Meniconi, S. & Capponi, C., Numerical analysis of the transient pressure damping in a single polymeric pipe with a leak. *Urban Water Journal*, **15**(8), pp. 760–768, 2018. DOI: 10.1080/1573062X.2018.15477.

[4] Grieves, M. & Vickers, J., Digital twin: mitigating unpredictable, undesirable emergent behavior in complex systems. *Transdisciplinary Perspectives on Complex Systems*, Springer: Cham, pp. 85–113, 2017.

[5] Zheng, C., Yuan, J., Zhu, L., Zhang, Y. & Shao, Q., From digital to sustainable: A scientometric review of smart city literature between 1990 and 2019. *Journal of Clean Production*, **258**, 2020. DOI: 101016/j.jclepro.2020.120689.

[6] Glaessgen, E. & Stargel, D., The digital twin paradigm for future NASA and U.S. air force vehicles. *53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference*, April, Honolulu, Hawaii, 2012. DOI: 10.2514/6.2012-1818.

[7] Nuzzo, A., Tan, C.O., Raskar, R., De Simone, D.C., Kapa, S. & Gupta, R., Universal shelter-in-place versus advanced automated contact tracing and targeted isolation: A case for 21st-century technologies for SARS-CoV-2 and future pandemics. *Mayo Clinic Proceedings*, **95**(9), pp. 1898–1905, 2020.

[8] Hauashdh, A., Jailani, J., Rahman, I.A. & AL-Fadhali, N., Strategic approaches towards achieving sustainable and effective building maintenance practices in maintenance-managed buildings: A combination of expert interviews and a literature review. *Journal of Building Engineering*, **45**, 103490, 2022. DOI: 10.1016/j.jobe.2021.103490.

[9] Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J. & Aharon, D., *Unlocking the Potential of the Internet of Things*, McKinsey Global Institute, 2015. https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world.

[10] Olivotti, D., Dreyer, S., Lebek, B. & Breitner, M.H., Creating the foundation for digital twins in the manufacturing industry: An integrated installed base management system. *Information Systems and e-Business Management*, **17**, pp. 89–116, 2019.

[11] Tao, F., Zhang, H., Liu, A. & Nee, A.Y.C., Digital twin in industry: State-of-the-art. *IEEE Transactions on Industrial Informatics*, **15**, pp. 2405–2415, 2019.

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REINVENTING THE IMAGE OF CITIES USING THE ELEMENT OF WATER: INTERNATIONAL CASE STUDIES OF WATERFRONT URBAN DEVELOPMENTS

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ABSTRACT

The relationship between human settlements and water has been complex and multidimensional throughout history. However, the urban history of cities is intrinsically related to their interaction with the element of water. The element of water enables spectacles to occur. People gravitate towards the water's edge, socio-cultural life improves, new spaces are discovered, and, in turn, the city is reconciled with the waterfront (natural harbour/river) by invigorating the civic realm via the activation of public space(s). The conference paper focuses on exploring four different international urban master-planning projects (Casablanca in Morocco, Hong Kong Special Administrative Region in China, Liverpool in the United Kingdom and Shanghai in China), which utilise the element of water (natural harbour/river) as a means of reinvigorating major district(s) within city centres via the process of reconciliation, and in turn, reinventing the image of the city. The main aim of the research team is to understand the dynamics behind these urban master-plan projects and to highlight the new aspects of the process of re-evaluation/re-invention of the city's identity and urban character through reconnecting to the water's edge (natural harbour/river) and regenerating the waterfront. In summary, this paper is an attempt to express the significance of integrating water as a unified natural element and as an essential landscape feature within urban master-planning visions leading to a more sustainable future for our cities globally, as well as to highlight the new urban design aspects of the process of re-evaluation and re-invention of the city's identity and urban character. The main drive of the paper is that emphasising links to the element of water should be considered a key lead urban design factor within the regeneration of cities internationally.

Keywords: international cities, sustainability, waterfront developments, urban developments, urban planning, urban regeneration.

1 INTRODUCTION

Water is considered the lifeblood of human society. The existence of water has always been a fundamental determining factor in the location, emergence and growth of human settlements. It has also been one of the essential elements and articulating aspects of our surrounding landscape. Water availability, whether in the form of rivers, streams, sea, or ocean, widely explains the emergence of urban settlements by human societies. In fact, the relationship between human societies and water is far more complex than it appears. Water impacts urban life beyond purely biological or environmental considerations and contributes to grounding people in spaces, creating the social tissue and identity of the local community beyond administrative limits [1].

Moreover, water was considered a source of spiritual purification, change, and revival. Since the dawn of time, humans have revered the water in rivers, springs, and oceans. Water has the ability to change, purify, and inspire, as well as allow for transition and metamorphosis. At the same time, it has served as a symbol of imagination, spirit, creativity, and human aspiration, as well as a target for unlimited manipulations. The flowing of water is a constant memory of the changing and the ephemeral [2].

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However, this intimate connection to water has gradually vanished with the rise of industrialisation and rapid urbanisation, particularly in the 20th century. As a result, the relationship between cities and their waterscapes became more complex and multidimensional. Cities have experienced population booms and urban expansion, while the water landscape hasn't been given much importance in this situation [2]. Unfortunately, in several cities, the focus on the densification of urban areas has led to the decline, abandonment and degradation of several waterfront areas. Such areas simply became the domain of heavy industries, transit, or waste disposal, rarely seen by most city residents [3]. This trend of disdain for waterfront areas has reached many cities around the world.

As waterfront cities began to develop post-industrial urban development strategies throughout the 1970s to our present time, urban waterfronts became central to urban renewal and regeneration throughout the world [3]. As a result, several cities are trying to reinvent their connection with water and create a progressive reconciliation with their waterscapes. This reconciliation results in articulated and sophisticated structures that characterise the physical appearance of cities and their image to the rest of the globe. The reason for this movement is the growing interest in switching lifestyle from quantity to quality: a creation of affluent water space, a recycling-oriented society, etc. [2]. In this context, waterfronts are considered opportunities for the city as a whole [4], particularly in rebranding its image locally and internationally. Furthermore, the waterfront's role has been enhanced by its position as an important node for the land and sea and an entrance through which the city develops relationships with other areas [5]. As a result, waterfronts have become an important part of the broader concept of the city and the region [6].

The reconnection of cities to water, and the development and implementation of new urban strategies aimed at redeveloping urban waterfronts, have resulted from different approaches: namely, the restructuring of water-front activities, the increased importance of leisure and tourism, and growing concern for environmental issues over the last few decades. Moreover, these strategies varied depending on the urban, economic, social and cultural contexts of the city.

In fact, since waterfronts have become the areas in which the urban image is reconstituted [6]. Several global cities such as Casablanca (Morocco), Hong Kong Special Administrative Region (SAR) (China), Liverpool (United Kingdom) and Shanghai (China) have waterfront redevelopment projects at the forefront of their main urban schemes using different approaches. This article explores these different urban/water reconnection approaches and rebranding processes by examining four international case studies of influential waterfront projects in these cities. Starting with different urban, economic, social and cultural contexts, we try to understand how these case studies use waterfront regeneration projects to reinvent their urban image. We aim to study the dynamics behind these projects and highlight the new aspects of the re-evaluation and re-invention of cities' identity and urban characters. We try, through this study, to highlight different examples of successful approaches that other cities around the world can adopt to recreate their connection with their surrounding waterscape and to benefit their image locally and internationally.

2 MOTIVATIONS FOR THE CREATION OF THE PAPER

The professional and academic expertise of the authors (dispersed internationally) lies within the disciplines of architecture (Hui), arts and culture (Roberts) and urban design and development (Benabbou and Shao). The authors' detailed knowledge and previous research of urban developments/redevelopments combined with the Wessex's Sustainable Cities 2022 Conference's focus on "City/Waterfront Interaction" [7] motivated the authors to further

investigate four waterfront urban developments within the international cities of Casablanca (Morocco), Hong Kong SAR (China), Liverpool (United Kingdom) and Shanghai (China).

The title of this paper makes direct reference to Kevin Lynch's book *The Image of the City* [8]. In his seminal work, Lynch proposed a set of urban design principles for the betterment of urban developments/redevelopments, hoping that future cities/urban districts will be places that are memorable, navigable and pleasurable to the city-user within the context of his/her mental map. However, Lynch also points out that "there are other influences on imageability" [8], such as the city user's emotions [9], [10] invoked by the sense of place (*genius loci*), provision of high-quality public space/civic amenities, connection to natural elements for respite and the new image of the place creating a new identity of the city (personal/collective meaning).

The origin of this paper can be first traced to Hui and Mak's [11] establishment of the association between the building typology of the International High-Speed Rail (IHSR) station(s) (St. Pancras International Station and West Kowloon Station) and the integration of master-plan led urban developments ((King's Cross Central Development) (West Kowloon Cultural District)) within the cities of London (United Kingdom) and Hong Kong SAR (China) [11]. Secondly, Roberts [12] established that the revitalisation of ex-industrial sites (798 Art Zone and 751 D-Park in Beijing, China) via the implementation of arts and cultural building programming, can lead to commercially viable schemes [12]. However, opportunities for further improvement within the realms of facilitating local enterprise development and improvement of social welfare were identified and viable strategies were proposed [12].

The findings from the Urban Maestro team [13] emphasise design quality is central to all urban developments/redevelopments. The design quality is further categorised into the sub-sectors: "culture", "capacity", "coordination", "collaboration", "commitment" and "continuity". Together with the recommendations (50 principles) laid out by the Charter of Public Space [14] for the betterment of public space(s), it is the authors' wish, besides analysing the physical characteristics of the four waterfront urban development schemes, to discuss the design quality of the schemes. The author also wishes to indicate the design features of the public space/civic realm within each specific urban waterfront development.

3 SUSTAINABILITY WITHIN THE CONTEXT OF URBAN DEVELOPMENTS

The concept of "sustainable development" has been developed and refined over time and reflects the vision of a harmonious economic, environmental and social development for all of humanity. In 1987, the United Nations published a study entitled "Our Common Future", which formally introduced the concept of sustainable development: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [15]. In 2015, all UN member states adopted the "Sustainable Development Goals" (SDGs), which set out a 15-year plan to achieve these goals, with 17 Sustainable Development Goals at the heart of the agenda [16] and a call to action for all countries, both developed and developing.

As the world responds to the concept of "sustainable development", urban researchers and architects have begun to re-examine the sustainability of cities in the 21st century. The city's waterfront is the origin of urban development, which increasingly faces challenges in terms of resources, energy, environment, urban transport, commerce, information and communication [17]. The regeneration of urban waterfronts is an important process for the sustainable and effective development of urban spaces, regional cultures and market economies.

4 ARTS AND CULTURE LEAD TO VIBRANCY

Since the 1980s, many waterfront regeneration schemes attest to the developing understanding amongst city planners that incorporating space and opportunities for arts and culture leads to vibrancy. Notably, officials in Liverpool have documented the city's regeneration journey "amassing over two decades of evidence on the impact and value of cultural interventions as catalysts for urban change" [18]. Spectacular waterside cultural events, such as the parades of giant puppets orchestrated by the Royal de Luxe company [19], generate tourism and enormous income and elevate the public mood.

Such activities perhaps satisfy the innate human urge for festivals and rituals, as identified by philosopher Mikhail Bakhtin in his theory of the "carnivalesque" [20]. The mundanity of routine existence is relieved by temporary and spectacular communal happenings which transport emotionally. Importantly, such magnetising cultural events also heighten the identity of location and aid the identification of individuals with the place: "The potential of festive-like events to influence place identity is…undertaken by cities seeking to rebrand or enhance communal identity…New shared traditions and symbols of common identity are essential if divided communities are to find commonality. And large-scale spectacular outdoor experiences ensure that all communities feel that they can participate" [21]. Access to joyous cultural events undoubtedly enhances community fulfilment, but the proximity of water, inducing feelings of well-being as mentioned above, augments the efficacy of cultural events and arts. Thereby, cyclically, public satisfaction is improved.

5 WATERFRONT URBAN DEVELOPMENT CASE STUDIES

After examining the background of this study, along with considering issues of sustainability and the inclusion of the arts and cultural activities, the next section will focus on the four selected case studies. The case studies will define the histories of the sites, the patterns of regeneration, the characteristic resulting features and the merit of the endeavours.

5.1 Waterfront urban development in Casablanca (Morocco): Casablanca Marina Project Development (CMPD)

Casablanca is the economic capital of Morocco. The city has a long, intimate and complex connection to the Atlantic Ocean as it symbolises its urban emergence, opening to the world and the door from which colonising threats came in the past. The latter has caused the city to give its back to the ocean for centuries, leaving the coastal area for harbour activities, heavy industries, or simply degradation. It was not until the 1990s that the coastal area started to attract the attention of the city's decision-makers. It resulted in the initiation of several coastal urban projects, including the Casablanca Marina project, targeting reconnection of the city to the ocean. The project was also born from the desire to enhance the Atlantic coast area and develop an urban waterfront that reinforces the branding strategies of the city as an economic hub. However, the project faced multiple logistic issues that delayed its construction for several years. Therefore, it did not start until 2001 and was rebooted again in 2005 [22]. The project was developed over a total area of 26 hectares, including 10 hectares reclaimed from the sea. It consists mainly of a central business district, residential areas, facilities and public spaces. The programme of the building covers a total surface area of 476,600 m^2 of floor space, excluding car parks, with multiple functions: offices: 33%, trade: 15%, hospitality: 12%, leisure facilities, services and entertainment: 10% and residential: 30% [23]. Today the project is already finished. Most of the buildings are already hosting companies, start-ups and new residents. The project became not only a business hub but also a vibrant public space

that reconnects the city to the ocean while linking two of the main city landmarks: The Casablanca Port and the Hassan II Mosque.

5.2 Waterfront urban development in Hong Kong SAR (China): West Kowloon Cultural District (WKCD)

The West Kowloon Cultural District (WKCD) (40 hectares) is located in the Yau Tsim Mong District (one of the most densely populated and vibrant in Hong Kong SAR). Interestingly, the WKCD schematic design went through numerous property developer(s)/architect(s)-led design iterations. The debate centred on the single developer/multi-developer led approach; the final winner was Foster + Partners Group Limited/multi-developer consortium in 2011 [24]. The WKCD is currently constructed in phases, with the overall completion targeted for 2040 (estimated). The WKCD development led by the WCKD Authority (Hong Kong Government (HKGOV) (WKCDA)) comprises mixed-use building programming, with a special focus on the creation of world-class standard arts and cultural facilities (major art galleries, museums and performance venues), highly connected by public transportation and highly accessible by the general public. Sustainable building features include green building certification and BEAM PLUS (Hong Kong Green Building Council) [25]. The WKCD is well served by public transportation and public space comprises over 50% of the overall site area. The WKCD is orientated towards the Central Business District (located on Hong Kong Island), directly facing the Victoria Harbour waterfront, with a promenade running the entire length of the development. In relation to the WKCD, the HKGOV's Harbour-front Enhancement Committee (HEC) [26] was set up in 2004. The HEC is responsible for the improvement of 22 No. Action Areas within 73 km of harbourfront within Victoria Harbour. The Vision of HK GOV HEC:

> "To enhance Victoria Harbour and its harbourfront area to become an attractive, vibrant, accessible and sustainable world-class asset: a harbour for the people, a harbour of life" [26].

5.3 Waterfront urban development in Liverpool (United Kingdom): Liverpool Waterfront Development (LWD).

Liverpool's waterfront is iconic due to the city's role as a major international port for several centuries. For two centuries, this port was the major departure point for those in Europe who wished to emigrate to North America and is recognised by its collection of buildings called the "Three Graces" [27] and by The Royal Albert Dock. Unfortunately, industrial decline, the city centre docks became increasingly derelict and dangerous throughout the 1960s and 1970s. The Mersey Docks and Harbour Board owners even considered demolishing the whole site [28].

However, in 1981, the Merseyside Development Corporation was set up to undertake the regeneration of the Royal Albert Dock complex. Arrowcroft Group was employed to complete the works with a budget of around £100 million [28]. This site is consequently one of the first notable examples of regenerating a derelict industrial area and was evidence that "During the 1980s there began to emerge a growing interest in the arts and culture as mechanisms for urban regeneration" [29]. The same area remains the focus of attention for developers in the 2020s. This might be because, as Marshall states, the waterfront of cities of the past were the generators of economic wealth. So regenerating these areas today connects our past with the future by "providing opportunities for cities to reconnect with their water's edge" [30].

5.4 Waterfront urban development in Shanghai (China): Shanghai West Bund Development (SWBD).

Shanghai is a provincial-level administrative region of China, one of the national central cities and the international economic, financial, trade, shipping, science and technology innovation centre of China as approved by the State Council of China. The city has 16 districts under its jurisdiction, and the west bank of Shanghai is located in the Xuhui Riverfront area in the southwestern part of Shanghai's central city. The Xuhui Riverfront is the only waterfront area in central Shanghai that can be developed on a large scale. Covering an area of 940 ha and a shoreline of 11.4 km, Shanghai West Bund is the most publicly vibrant new waterfront district in the centre of Shanghai.

In the 1930s, the west bund of the Huangpu River was a gathering place for the national industrial capital, with many industrial plants and logistics terminals along the river. Shanghai's first freight railway station, with the largest Longhua airport in the Far East, China's first wet-process cement plant, and Shanghai's first water and land transport terminal formed a productive shoreline for the industry. In the 1990s, Shanghai entered a period of urban transformation. The transition from the traditional economic system to a market economy and the renewal of production technology caused the traditional factories in the riverside area to fall on hard times [31]. In 2002, Shanghai was awarded the right to host the World Expo. In addition, the Comprehensive Development Plan of the Huangpu River was launched in 2010 [32], transforming the functions of the riverside areas on both sides of the Huangpu River, transforming the original production space into a living space and leading to the economic, social and cultural revival of the riverside areas.

The successful delivery of Expo 2010 Shanghai China, under the Expo's theme of "Better City, Better Life", helped to accelerate the development of the Shanghai West Bank project. The project is located across the river from the Shanghai World Expo Park and is an opportunity to enhance the international image of Shanghai, China and establish the city's name. Furthermore, the development of the Xuhui Riverfront during Shanghai's "Twelfth Five-Year Plan" in 2012 has become a new high point for the development of Shanghai's central region. It is one of the six functional areas of Shanghai. As one of Shanghai's six functional areas, the West Bund is "planning, culture-led and industry-led" in the overall development idea, with the additions of the "West Bund Cultural Corridor" brand project, the "West Bund Media Port" and the "Shanghai Dream Centre". The West Bund has been built around the "West Bund Cultural Corridor" brand project, the "West Bund Media Port", the "Shanghai Dream Centre" and other functional carrier projects. It is committed to building a cultural platform and a new cultural landmark for dialogue between Shanghai's international cultural metropolis and the world, as well as a complex structure supported by cultural creativity, artificial intelligence and innovation and finance [33]. The industrial heritage space in the West Bund has also been further transformed and utilised, and new connotations have been injected to sustain the heritage.

6 COMPARISON OF WATERFRONT URBAN DEVELOPMENTS

The four presented case studies are very diverse in terms of social, cultural and economic backgrounds. They also showcase different urban strategies to reinvent the cities' connection with their waterscapes. Therefore, in order to understand these dynamics and identify the similarities between the selected projects, we have decided to draw a comparison and assessment table that gathers all the significant data about each project (Tables 1 and 2).

Table 1: Comparison of the physical attributes of the waterfront urban developments in Casablanca (Morocco), Hong Kong SAR (China), Liverpool (United Kingdom) and Shanghai (China).

	Four international waterfront development projects			
	Casablanca Marina Project Development (CMPD)	West Kowloon Cultural District (WKCD)	Liverpool Waterfront Development (LWD)	Shanghai West Bund (SWBD)
Physical attributes				
Location	Casablanca (Morocco)	Hong Kong SAR (China)	Liverpool (UK)	Shanghai (China)
Primary hub focus	Business and social hub	Arts and culture hub	Historical, arts and culture hub	Financial, arts and cultural corridor
Associated waterfront	Atlantic ocean	Victoria harbour	Liverpool waterfront	Xuhui waterfront region of Shanghai
Orientation of development	Central business district and social public space	Central business district/ Hong Kong Island	International waterfront cultural and civic cluster	International waterfront cultural and financial cluster
Identity/character	Contemporary	Contemporary	Historic and contemporary	Contemporary

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Table 2: Comparison of the economic, cultural and social attributes of the Waterfront Urban Developments in Casablanca (Morocco), Hong Kong SAR (China), Liverpool (United Kingdom) and Shanghai (China).

	Four international waterfront development projects			
	Casablanca Marina Project Development (CMPD)	West Kowloon Cultural District (WKCD)	Liverpool Waterfront Development (LWD)	Shanghai West Bund (SWBD)
Economic benefits	• Creation of a business hub in the city • Attraction of international companies • Provision of office spaces for start-ups • Reviving the coastal area economically • Provision of conference halls/business meeting spaces	• Creation of a major arts and culture hub to showcase local and international works and talent • Creation of 16,000 jobs for the arts, commercial and retail sectors • A new attraction and destination for arriving and departing visitors (air and rail travel) to the city	• Historic civic hub in the city • Attraction of international galleries and nationally important museums • Reviving the coastal area economically • Provision of restaurants, bars, shops and historical artefacts • Local council offices	• High-quality public and cultural open space • Attracting international and multinational companies • International cultural and art gallery corridor • Provision of international conference and office space
Cultural benefits	• Provision of cultural facilities like theatres and plazas • Hosting cultural events and festivals	• Creation of new arts and cultural hub • Showing the importance of arts and culture (local and international) • Provision of spaces for festivals and performances	• Provision of cultural facilities like museums and galleries • Hosting large-scale international cultural events and festivals, e.g. “Tall Ships Festival”	• Provision of cultural facilities such as art galleries, art centres, theatres and art parks • Hosting cultural events and festivals such as art exhibitions, cultural festivals and music festivals

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Table 2: Continued.

	Four international waterfront development projects			
	Casablanca Marina Project Development (CMPD)	West Kowloon Cultural District (WKCD)	Liverpool Waterfront Development (LWD)	Shanghai West Bund (SWBD)
Social benefits	• Provision of large open public spaces for citizens • Provision of social space to enjoy the ocean view • Provision of shopping and leisure facilities (shopping malls, restaurants, marina) • Hosting social events and activities	• Open to the general public to use • Provision of additional public green space • Provision of affordable housing in line with policy • Provision of educational facilities	• Provision of large open public spaces for citizens and tourists • Provision of social space to enjoy the ocean view • Provision of arts and leisure facilities (shopping, art galleries/museums, restaurants, cruise terminal)	• Provision of large open public spaces for citizens and tourists • Provision of social space to enjoy river view • Provision of shopping, arts and leisure facilities (shopping, art galleries/museums, restaurants, cruise terminal, art park)

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After thoughtfully examining the information presented in Tables 1 and 2, the comparison highlights that these waterfront urban developments are very different in size, location, type of water bodies (ocean, river) and development orientations (business, arts, culture, finance, etc.). However, there are strong similarities in terms of the benefits (economic, cultural and social) that the city acquired through these projects.

The assessment shows that the four projects exhibit high urban design quality, illustrated through diverse building programming, and flexibility in design, in addition to ensuring connectivity with public transportation and continuity with the existing urban tissue, despite having different urban characters.

The projects are also characterised by high functional quality through good accessibility, security, connection, and service provision, all of which contribute to an enjoyable experience of the area for citizens.

On the environmental level, the respect and adoption of environmental policies are also considered and incorporated into their development strategies. Moreover, these waterfront developments appear to help their cities and citizens on the economic level and social and cultural levels by providing various benefits ranging from job creation to pleasant venues for social and cultural interactions. These benefits have enabled the cities to enhance residents' quality of life while improving their image locally and globally.

7 DISCUSSION

Having investigated the four international urban developments, it is evident that cities globally are simultaneously undertaking new high-quality urban developments on a grand scale. Such urban developments promise bold visions (new arts and culture/commercial hubs) for the future of the cities. They are marketed as new frontiers in terms of the re-invention of cities, thus setting the bar higher in terms of city-to-city competition and innovation (globally). However, such urban developments take decades to conceive (plan, design and construct). For example, in the CMPD (Casablanca, Morocco), SWBD (Shanghai, China) and WKCD (Hong Kong SAR, China) developments, construction is still ongoing. All four urban developments are located at the water's edge and utilise the element of water as a natural feature and landscape backdrop. The main difference lies in the building programming/mix and the overall size (26–940 ha) of the developments.

Due to the complex nature of building programming and mega-scale sizing of such urban developments, it is key that a certain degree of flexibility is factored in to allow for change-of-use in the medium to long term of the development's life span. Therefore, the recommendation would be for certain mixed-use building(s) to be "future-proofed", allowing for flexible building programming to cater to emerging trends/usages.

Besides urban renewal, governments (internationally) have invested large sums in such urban developments to reinvigorate urbanity, stimulate the economy and deliver cultural and social benefits to its citizens. However, it remains questionable to what extent such developments benefit all levels of society and what are the unintended consequences (both negative and positive) of gentrification and increased levels of tourism. Such questions are of interest and will be investigated further in the near future.

In terms of analysis, a number of limitations should be taken into consideration. First, the study has focused only on four case studies from three continents; further research including all continents may be needed to explore and compare international waterfront projects. In addition, these projects have explored the reconnection of cities to only two types of water bodies (ocean and river). Broader research, including other water body types like sea and lakes, may widen our perspective and understanding of the urban dynamics of such projects on the local and international levels.

8 CONCLUSION

The researchers have presented four international waterfront urban development case studies. These cases reinvent the image of existing cities via the creation of new large to mega-scale (sized at 26–940 ha range) masterplan-led urban developments within the existing city urban fabric linked to the element of water. The term "reinvent" relates to the aspiration of city planner(s) and government(s) to reinvent the city's identity for citizens and visitors alike; such new urban developments present a new image of the city, encapsulating the past, present and presenting a bolder vision for the future. More so, the urban developments (each with their focus, be it arts and culture, commercial or financial hubs) create entirely new district(s) within cities, energised by mixed-use building programming, provision of the high-quality urban environment(s), linkage to major nodes of public transportation and adhering to sustainable design principles. Common to all four urban developments is the water's edge (harbourfront/riverside) proximity. Cities are linked to the element of water as their origin. Once again, the element of water becomes a revered and valuable asset with which all can engage and participate, thus providing impetus for new cultural, economic and social opportunities.

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REFERENCES

[1] Schiavo, F., City and water: Strategies, planning and management. A comparative study of the cities of Barcelona, Milan and Lisbon. PhD thesis, Universitat de Barcelona, Geography, Territorial Planning and Environmental Management, 2007.

[2] Sakura, K., The relationship between urban structure and waterways in Edo, old Tokyo. *Irrigation, Society and Landscape*, Tribute to Tom F. Glick, **3**, pp. 924–934, 2015.

[3] Davidson, M., Urban geography: Waterfront development. University of Western Sydney: Sydney, Australia, 2013.

[4] Smith, H. & Ferrari, M.S. (eds), *Waterfront Regeneration: Experiences in City-Building*, Routledge, Abingdon, 2012.

[5] Papatheochari, D., Examination of best practices for waterfront regeneration. *Littoral 2010: Adapting to Global Change at the Coast: Leadership, Innovation, and Investment*, 02003, 2011.

[6] Yildiz, R., Selier, N. & Ozyilmaz Kucukyagi, P., Critical review of recent waterfront regeneration projects in Istanbul. *Proceedings of the 12th International Conference on the Mediterranean Coastal Environment, MEDCOAST*, 2015.

[7] Wessex Institute of Technology, *Sustainable City 2022: 16th International Conference on Urban Regeneration and Sustainability*, WI Press: Southampton and Boston, 2022. https://www.wessex.ac.uk/conferences/2022/sustainable-city-2022. Accessed on: 22 May 2022.

[8] Lynch, K., *Image of the City*, MIT Press: London, 1960.

[9] Lee, H. & Benabbou, R., Exploring the evolution of urban emotions in the city of Seoul using social media information. *International Journal of Knowledge-Based Development (UKBD)*, **10**(3), 2019. DOI: 10.1504/ijkbd.2019.10024724.

[10] Benabbou, R. & Lee, H., Mapping urban emotions of Seoul: Using social media emotion information to explore the urban landscape of the city. *Spaces and Flows: An International Journal of Urban and Extra Urban Studies*, **9**(3), 2018.

[11] Hui, Y. & Mak, M., International high-speed rail stations' airports' in city centers. *Advances in Civil Engineering Materials. Lecture Notes in Civil Engineering*, eds A.M.M.F. Bin Meor Razali, M. Awang & S.S. Emamian, Springer: Singapore, 2021. DOI: 10.1007/978-981-33-6560-5_8.
[12] Roberts, E., What aspects of participatory design can help urban revitalisation; in particular in the restructuring of former industrial zones in China. Devtracker.fcdo.gov.uk, 2022. https://devtracker.fcdo.gov.uk/projects/GB-GOV-13-FUND--Newton-AH_S003517_1/summary. Accessed on: 2 May 2022.
[13] Urban Maestro, New governance strategies for urban design. Urban Maestro, 2022. https://urbanmaestro.org/resources/. Accessed on: 2 May 2022.
[14] UN Habitat, Public Space Charter. UN Habitat, 2022. https://habnet.unhabitat.org/sites/default/files/documents/Charter%20of%20Public%20Space.pdf. Accessed on: 2 May 2022.
[15] Emas, R., The concept of sustainable development: definition and defining principles. *Brief for GSDR*, pp. 1–3, 2015.
[16] Hak, T., Janouskova, S. & Moldan, B., Sustainable development goals: A need relevant indicators. *Ecological Indicators*, **60**, pp. 565–573, 2016. DOI: 10.1016/j.ecolind.2015.08.003.
[17] Shao, J., Zhou, H., & Seiyong, K., Research on energy-saving architecture design concept of urban based on sustainable development. *Northern Architecture*, **5**(4), pp. 23–28, 2020. DOI: CNKI:SUN:BFJZ.0.2020-04-012.
[18] Culture Liverpool, https://www.cultureliverpool.co.uk/liverpool2018/culture-the-catalyst-of-liverpools-re-introduction-to-the-world/. Accessed on: 5 Jun. 2022.
[19] Royal de Luxe, https://www.royal-de-luxe.com/en/creation/liverpools-dream/. Accessed on: 1 Jun. 2022.
[20] Bakhtin, M., *Problems of Dostoevsky's Poetics*, University of Minnesota Press: Minneapolis, 1984.
[21] Jordan, J., Festivalisation of cultural production: Experimentation, spectacularisation and immersion. *Journal of Cultural Management and Policy*, **6**(1), pp. 44–55, 2016.
[22] Barthel, P.A., Faire du "grand projet" au Maghreb. L'exemple des fronts d'eau (Casablanca et Tunis). *Géocarrefour*, **83**(1), pp. 25–34, 2008.
[23] La Companie Generale Immobiliere, Casablanca Marina, Casablanca, Morocco. https://www.cgi.ma/sites/default/files/2021-06/Brochure%20CASABLANCA%20MARINA.pdf.
[24] West Kowloon Cultural District, https://www.westkowloon.hk/en/. Accessed on: 2 May 2022.
[25] BEAM Plus New Buildings, https://www.hkgbc.org.hk/eng/beam-plus/beam-plus-new-buildings/. Accessed on: 2 May 2022.
[26] Bureau (www.devb.gov.hk) D. Home, Harbour-front Enhancement Committee. https://www.harbourfront.org.hk/eng/index/index.html. Accessed on 18 Jun. 2022.
[27] Zwegers, B., Shanghai-Upon-Mersey. Conservation and change in Liverpool. *Cultural Heritage in Transition*, ed. B. Zwegers, Springer: Cham, pp. 237–263, 2022.
[28] Royal Albert Dock Liverpool, https://albertdock.com/history. Accessed on: 18 Mar. 2022.
[29] Couch, C. & Farr, S., Museums, galleries, tourism and regeneration: Some experiences from Liverpool. *Built Environment*, **26**(2), pp. 152–163, 2000.
[30] Marshall, R., *Waterfronts in Post-Industrial Cities*, Taylor and Francis: London, p. 5, 2001.

[31] Ding, F. & Wu, J., Research on the mechanism of post-industrial urban waterfront revitalization in the background of globalization: Taking the West Bund of Shanghai Huangpu River as an example. *Modern Urban Research (CN)*, **1**, pp. 25–34, 2018.
[32] Jin, Y., Cui, Y. & Liang, Y., Analysis on the production mechanism of urban waterfront space under the concept of people's city: Taking Shanghai West Bund as an example. *Landscape Architecture (CN)*, **38**(5), pp. 28–33, 2021.
[33] China Government Network, http://www.gov.cn/xinwen/2019-11/07/content_5449864.htm. Accessed on: 7 Nov. 2015.

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INDEX OF VULNERABILITY TO POLLUTION OF KARSTIC COASTAL AQUIFERS: ANALYSIS OF FACTORS FOR THE URBAN ZONE OF PLAYA DEL CARMEN, MEXICO

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ABSTRACT

The present study proposes four factors for the construction of a vulnerability index in relation to the pollution of coastal aquifers in urban karst areas. It considers three environmental factors (climate, relief and rise in sea level) and one anthropogenic (use of land), with greater importance given to the latter, as the intention is to work with the premise of being a built-up area, as is the case with Playa del Carmen, Mexico. For each factor, the following variables were considered: (1) Relief: frequency of depressions and form type, depending on their morphological features; (2) Climate: with the Modified Fournier Index; (3) Rising sea level: with the modelling of sea level rise, potentiometric surface level and distance from the coast; and (4) Use of land: differentiated by the secondary zoning of the urban development program and land population co-efficient of occupation. For the relief factor, the most vulnerable areas were identified at the north and southern extremes of the urban area with a frequency of 30 to 37 depressions and a predominance of sinkholes and sinkholes-uvalas. The Modified Fournier Index is from 198.46 to 200.74, with a distribution of high vulnerability to the south-east; the land use factor shows high to very high vulnerability distributed throughout most of the city. a sea rise projection of 1 to 3 m is identified in the first 2 km with respect to the coastline, at a distance from the coast of 1 to 3 km and a constant potentiometric surface level for the entire study area. Finally, the uses are designated as commercial, residential tourism, high housing and mixed uses.
Keywords: karstic depressions, rainfall, saline intrusion.

1 INTRODUCTION

The development process of man has given the guidelines to properly conceptualise elements linked to his habitat, environment and a possible relationship between these [1], leading to an interest in learning about the vulnerability of ecosystems. The concept of vulnerability to the contamination of groundwater was introduced by Albinet and Margat [2] and began a great interest in this area. The definition of vulnerability to contamination from Zwahlen [3] was taken up again for this study: “Features from hydrogeology, soils, relief, climate and vegetation, inherent to the system as a whole that determine the susceptibility to contamination by anthropic activities”.

Since then, there are currently different models proposed to calculate the vulnerability of aquifers to contamination due to the different ecosystem’s characteristics. The first to appear were DRESTIC, SINTACS and GOD [4]. Emphasis was then placed on indices for karst areas such as EPIK, PI, COPK, KARTIC, RISKE, the Slovenian approach, PaPRIKa, KAVI, LEPT, and APLIE [5]. These models have a hydrogeological approach [6]. While the IVAKY model of Aguilar-Duarte et al. [5] proposes a combination of multiple factors, such as relief, climate and land. However, urban development in karstic coastal areas is a relevant aspect due to population growth, the expansion associated to irregular settlements and the replacement of natural environments it brings which implies a significant land use change [7].

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Thus, it is necessary to consider criteria associated with these problems, so it would be ideal to use the land use criterion as the main factor that directly influences the vulnerability degree to aquifer contamination, since urban infrastructure works as a waterproofing, reducing infiltration and increasing pollutants [8] and has a direct influence on recharge and infiltration [9]. Likewise, it is proposed to consider specific problems for coastal areas, such as climate change [10], [11] and incorporate criteria such as the rise of the sea [12] and the distance respect to the coastline, because of contamination can also occur on a horizontal plane [13], [14].

Based on the above, the objective of this study was to propose factors to design an index for the vulnerability to contamination of karst-coastal aquifers in built-up areas on a small scale and apply it to the coastal city of Playa del Carmen, Mexico.

2 MATERIALS AND METHODS

2.1 Study area

The city of Playa del Carmen, with a land area of 2,205 km^2 and a coastline of 87.20 km, is in the Mexican Caribbean, in the Cancun–Tulum corridor, to the east of the Yucatan peninsula. Specifically, between the extreme geographic coordinates: 20° 45' north and 19° 46' south in latitude and 86° 57' east and 88° 05' west in longitude (Fig. 1). Playa del Carmen is located within the RH33 hydrogeological region, while the rest of the municipality is within the RH32 region. Characterized by the absence of surface rivers but it does have several water systems: lagoons, cenotes, wetlands [15].

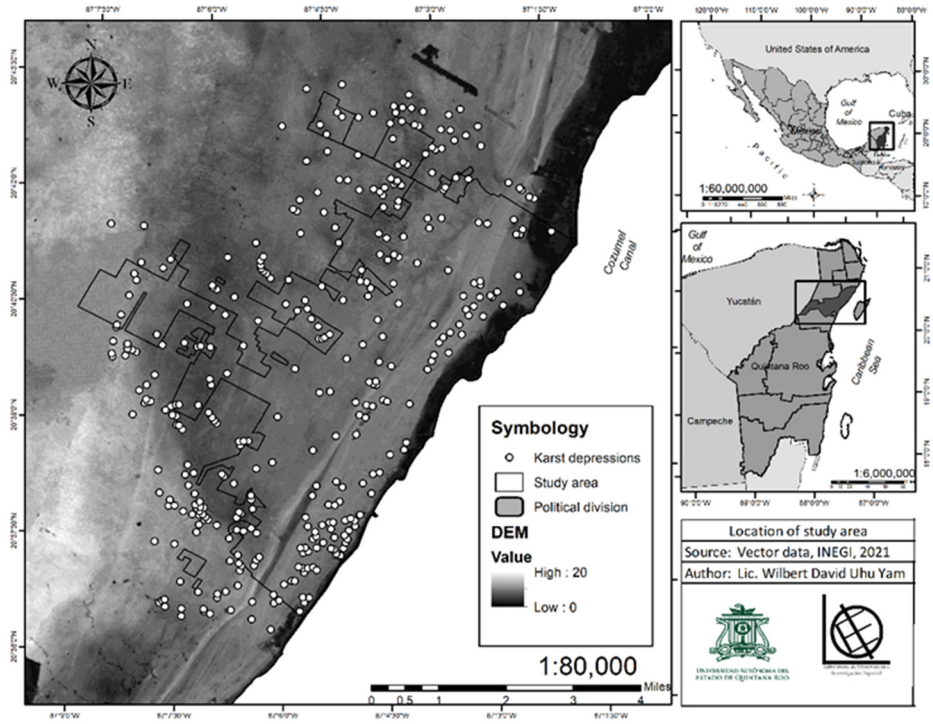

Figure 1: Location of the built-up area of Playa del Carmen.

3 TECHNIQUES AND TOOLS

3.1 Five study phases were established

3.1.1 Phase 1: Relief

For this factor, two indicators were considered: (a) the frequency of topographic depressions, with the karst depressions being identified first by taking the process described by Frausto-Martínez et al. [16] and Colín-Olivares et al. [17] as a reference and processing the 5 m resolution LiDAR data in ASCII/GRID format from INEGI. Subsequently, considering the land use polygons of the secondary zoning of the urban development plan, the frequency of karstic units was calculated; (b) karst depression predominantly by identifying morphometric features according to the proposals by Colín-Olivares et al. [17] and Rodríguez-Castillo et al. [18]; then classifying them into sinkholes, uvalas and poljes, as proposed by Fragoso-Servón et al. [19] and Frausto-Martínez et al. [20]. The frequency of the type of depression by land use was calculated. Finally, a weight was assigned on a scale from 1 to 10, using a hierarchical structure for each indicator, with the aim of homogenizing the data and obtaining a single map for the relief factor.

3.1.2 Phase 2: The Modified Fournier Index (MFI)

Proposed by Arnoldus [21], The Modified Fournier Index was calculated, with monthly precipitation data, in a period of 28 years (1990–2018) from 11 meteorological stations of the National Water Commission. The calculation is monthly, annual and for the observation period according to the suggestion of PHI-LAC [22]. Subsequently, in the ArcGIS v.10.8 software, a spatial analysis and the construction of distribution isolines were performed using the inverse distance weighting (IDW) interpolation technique. Finally, the data was taken only for the study area.

3.1.3 Phase 3: Sea level rise

Rise of the sea was analysed from three indicators: (a) Sea level rise considering the projections made for Mexico of 1 and 3 m [15] using the digital elevation model (MDE) created from the digitization of the contour lines and interpolation of the altitude data with ArcGIS v.10.8 software tools; (b) Piezometric level, calculated from the IDW interpolation of 22 sampling wells located in the municipality of Solidaridad; and (c) Distance from the coast–inland, using the technique of area of influence at each kilometre with respect to the coast. Subsequently, a weight was assigned to each indicator on a scale of 1 to 10, using a hierarchical structure and, finally, a summative analysis of the weights of each indicator was applied, with the aim of homogenizing the data and obtaining a single map to this factor.

3.1.4 Phase 4: Land uses

considering that it is an urbanized area, were analysed based on the differentiation designated by the secondary zoning of the land uses of the Urban Development Program (PDU) of the Playa Del Carmen population centre, Solidaridad Municipality 2010–2050 available at http://www.ccpy.gob.mx/archivos/documentos-agendas/tmp_201509113740.pdf. Based on the available Shapefile, a new one was created to group them into 10 land uses according to the permitted activities and the highest category proposed by the same PDU. Subsequently, the degree of vulnerability was assigned to each one according to the considerations of Pousa et al. [8] and Carretero and Kruse [23], as well as the relationship with the land occupation coefficient (LOC), this indicates the total area that can be occupied to build.

3.1.5 Phase 5

With the results obtained from each variable (relief, climate, rise of the sea and land use) the minimum and maximum data were taken to divide them into five quantiles equivalent to each of the five vulnerability categories (very low, low, medium, high and very high). Subsequently, the Analytic Hierarchy Process (AHP) method, proposed by Thomas Saaty in 1980, was applied to obtain priority scales based on expert judgements through pairwise comparisons using a preference scale. Once the weight of each variable was obtained, the following formula was used for each factor:

$$(V1 \times p) + (V2 \times p) + (V3 \times p) = \text{Degree of vulnerability},$$

where:
V: is the variable;
p: is the weight obtained.

Finally, all the information obtained for each factor was imported into ArcGIS 10.8 software, in order to obtain a geographic information system to create the raster models for each factor.

4 RESULTS

The results are presented according to the analysis criteria.

The weights assigned for each variable were: relief; for the frequency of depression 0.75, being the most important variable and 0.25 for the predominance by type of depression. As the climate factor was analysed with only one variable, it was not necessary to apply this method. Similarly, sea level rise was not applied, as the piezometric level is homogeneous for the whole area and sea level rise projections were only included in the very high category, due to the difference in the unit of measurement compared to the distance from the coastline. And finally, for land use, a higher weight (0.83) was given to the permitted uses in each zone and the land occupancy coefficient was given a weight of 0.17.

4.1 Relief

Using remote sensing inputs, a total of 364 karst depressions located in the urban area of Playa del Carmen were identified. According to the elongation index, 23.90% correspond to sinkholes, 43.13% to sinkholes-uvalas, uvalas represent 12.63% and poljes represent 20.23%. With the frequency of units and type of depressions, the most vulnerable areas were identified in the northern and southern limits of the urban area, where residential and mixed tourist land use predominates, which are classified as areas of urban growth, with a frequency from 29 to 37 sinkholes and sinkholes-uvalas type depressions (see Fig. 2 and Table 1).

4.2 Climate

The minimum historical annual regional rainfall was recorded at the Centro Vallarta station, with 67.3 mm and the maximum at Playa del Carmen with 2,790.4 mm. The average 28-year Modified Fournier Index ranged from 130.7 to 224.1. The highest value was at the Cancun station, which was classified within the very high rainfall category, according to the PHI-LAC classification [22]; and the minimum value was recorded at Centro Vallarta, classified in the high category. For the urban area of Playa del Carmen, the values range from 185.02 to 200.74, according to interpolation data mainly from the only meteorological station within

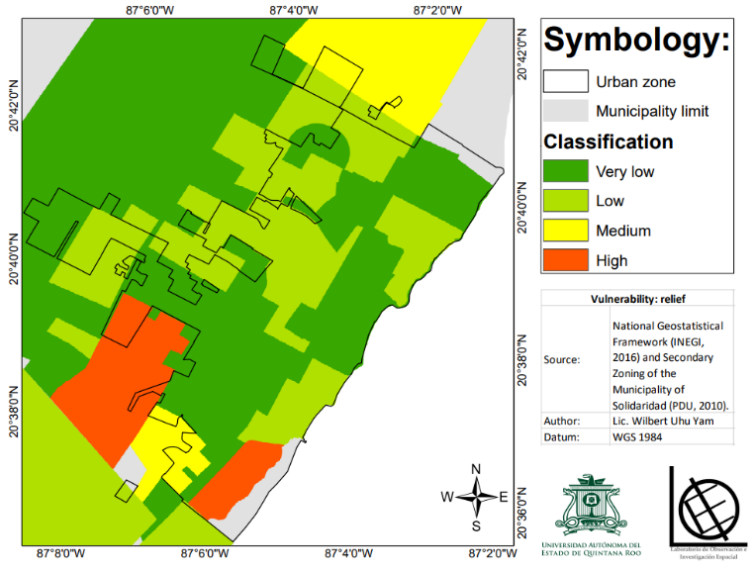

Figure 2: Vulnerability map by factors: relief.

Table 1: Description of the vulnerability categories.

	Description				
	Relief		*Climate*	*Sea level rise*	
Category	Frequency	Predominantly	MFI	Distance from the coast (km)	Rise in sea level (m)
Very low	<7	sinkholes, sinkholes-uvala	185.02–189.58	7–9	–
Low	8–19	sinkholes, sinkholes-uvala, poljes and uvalas	189.59–192.97	6–7	–
Medium	20–27	sinkholes-uvala	192.98–195.87	5–6	–
High	28–27	sinkholes-uvala	195.88–198.46	3–5	–
Very high	–	–	198.47–200.74	1–3	1–5

the study area and the closest stations (Cozumel and Centro Vallarta). Identifying a greater vulnerability to the southeast of the urban area with values of the Modified Fournier index from 198.46 to 200.74 (see Fig. 3 and Table 1).

4.3 Sea level rise

Considering that the groundwater is found a few meters deep and that the altitude in the urban area does not exceed 11 m above sea level, the projections of the increase in sea level for the year 2100, which are from 1 to 5 m, were considered. Specifically, 57.96% of the karstic depressions would be affected. At the potentiometric surface level, 22 wells ranging from

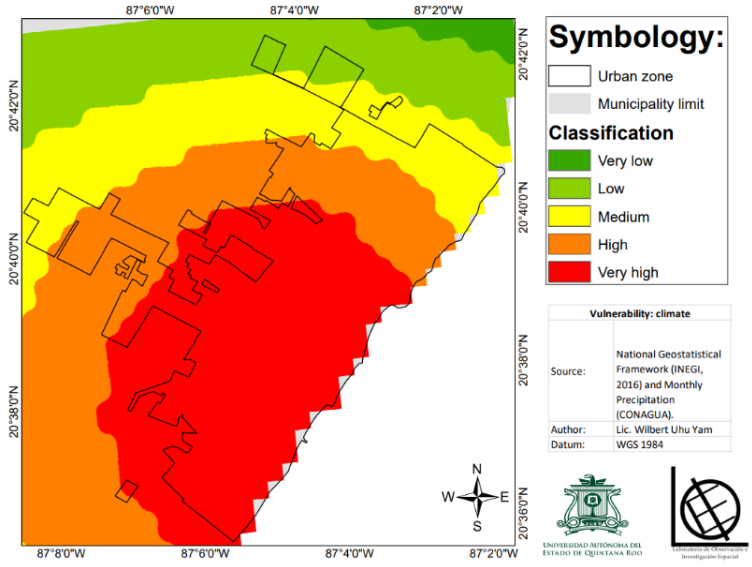

Figure 3: Vulnerability map by factors: climate.

2.15 to 19.11 m obtained a constant potentiometric surface level of 6.40 m for the city with the interpolation analysis, with the distance from the coast divided into kilometres. The areas with greater vulnerability were found within the first 3 km of coastline (see Fig. 4 and Table 1).

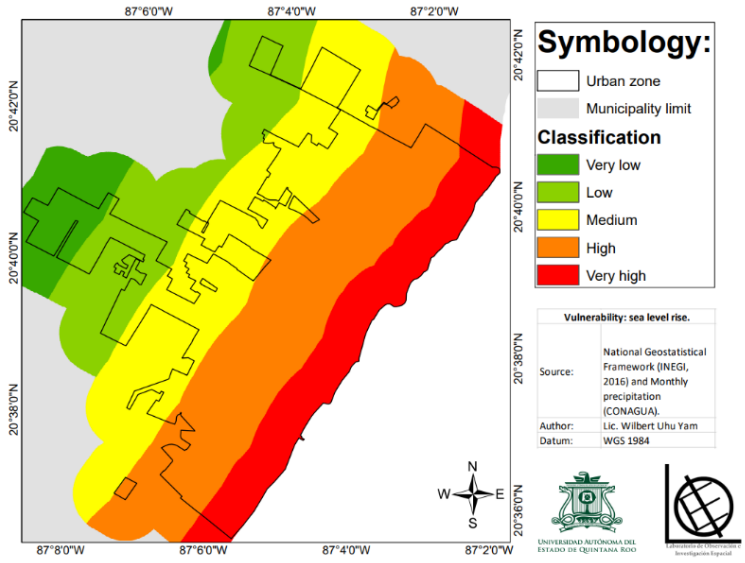

Figure 4: Vulnerability map by factors: sea level rise.

4.4 Land use

There were 24 uses identified, classified into 11 groups, according to the activities allowed in the urban development plan. A high to very high vulnerability was attributed for most of the city, for mixed use, growth, high rise residential, low intensity industrial and commercial. Within the city, protection zones associated with karst depressions, mangroves and jungle zones were identified (see Fig. 5 and Table 2).

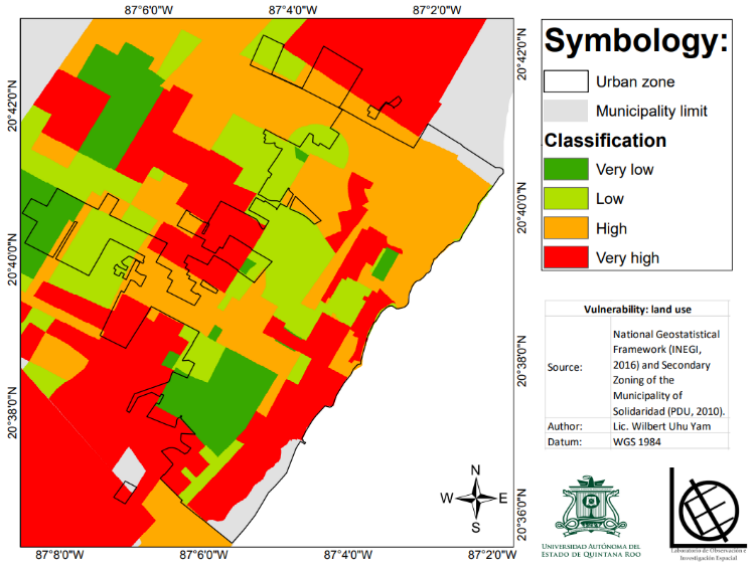

Figure 5: Vulnerability map by factors: sea level rise.

5 DISCUSSION

The growth of cities in the coastal areas of the north-east of the Yucatan Peninsula is one of the most significant aspects, with very high population growth and expansion rates, associated with the development of irregular settlements, a lack of urban planning and wastewater treatment services, coupled with the impact on highly sensitive natural environments, such as caves, caverns, and cenotes [21].

This type of urban growth in karstic areas affects the quality of the water systems, since manufacturing, storage and transportation activities that contain potential substances for the contamination of groundwater are carried out in them. Likewise, this factor plays an important role since it affects the recharge of aquifers in two ways: (a) it potentiates it due to the reduction of the impermeable cover, urban runoff from dry wells and their subsequent infiltration, sewage exfiltration and water pipes and excessive irrigation; and (b) recharge decreases, due to impermeable surfaces, the capture of water by the pluvial network and the extraction of water [24].

Due to these properties, studies such as those by Howard and Gerber [24] and Serra et al. [25], have considered the uses of land and soil for the study of groundwater contamination, while Heiß et al. [26] has annexed this factor together with the analysis of the DRASTIC index and González-Herrera et al. [27] modified this same index, adding the use of land.

Table 2: Vulnerability categories according to land use.

Category	Land use	Description
Very low	Protection	They are intended for the conservation of wells and wetlands, in these areas building of any kind is not allowed
Low	Equipment, urban parks and country tourism	They are intended for public administration buildings and services such as sports centers, schools, etc.
Medium	Low intensity housing	The construction of 20 houses with a frequency of 72 people per hectare is allowed
High	Commercial, residential tourism and industrial	The construction of 40 houses per hectare is allowed and can be used for markets, canteens, vehicle workshops, gas stations and restaurants. The construction of 25 houses or 50 rooms per hectare and should not exceed four levels. Is intended for the light industry such as storage and packaging of lubricants, storage of products that do not imply high risk and gas distribution
Very high	High intensity housing and mixed	The construction of 60 houses with a frequency of 216 people per hectare is allowed. In addition to the construction of 60 homes per hectare and can be used for commercial, residential, equipment and industrial activities

Due to the advanced process of urbanization in the coastal zone, it is necessary to consider the effects of climate change that favour the acceleration of sea level rise, affecting ecosystems. This increase can affect the total submergence or an increase in coastal flooding, loss or changes in habitats (including islands), coastal erosion and saline water intrusion into surface waters and aquifers [28] and the presence of extreme events such as cyclones, rainfall and floods [29]. The study by Ruiz-Ramírez et al. [15] shows the sea rise scenarios for Playa del Carmen, highlighting the damage caused by the rise of the sea, since it estimates an affectation of 90,895 m^2 with a rise of 3 m.

The relief and climate factors were considered in the vulnerability index of Aguilar-Duarte et al. [5] for the Yucatan aquifer. However, the relief factor was not given the same degree of importance here, as this index proposal was focused on urban areas. Despite this, a morphometric analysis of the karst units was performed on a detailed scale (1:10 000) with the help of relatively new methodologies [16]–[18]. The climate factor can be analysed with different indexes, such as the annual rainfall amount and intensity used in the COP model or the spatial distribution of the duration of the rainy period used in the IVAKY model [5]. However, it was decided to use a simple option for calculation, based on the information available, using rain erosion from the Modified Fournier Index, as it complies with the functionality of indicating the areas of greatest rainfall intensity. Thus, the greater this is, the greater the infiltration of water and contaminants, with the water operating as a transport medium for contaminants towards the aquifer [30].

Regarding the vulnerability results by factor, it is observed that the climate behaves inversely to the results reported for the state of Yucatan with the IVAKY model, where the greatest vulnerability is found in the centre of Yucatan and thus the coast decreases [5]; in

the relief factor a more homogeneous distribution is distributed and with a tendency to a high and very high vulnerability for both studies; for sea level rise, the highest vulnerability is found in areas very close to the coast, coinciding with the studies by Chachadi and Lobo-Ferreira [13] and Blanco de la Paz et al. [14].

6 CONCLUSIONS

Pollution vulnerability indices are of great importance for territorial management. However, the proposals to calculate it have been modified according to the needs and characteristics of each area studied. The proposal of this study incorporates the land use factor and the rise in sea level as central elements as it is an urbanized coastal area. These factors had not been taken into consideration when developing vulnerability indices for the Yucatan Peninsula. The methods used to analyse the land use and relief factors allowed us to work at a detailed scale (1:10,000). However, due to the climate factor, it was not possible to generate information with a degree of detail less than 1:50,000 due to the dispersion of local meteorological stations. For the sea rise factor, the records on the piezometric level are scarce. It contributes to define an approach to the analysis of vulnerability to contamination of coastal karstic aquifers in urban areas on a scale and a change of traditional approach where only the natural characteristics of the ecosystem are considered.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Cardona, O.D., La necesidad de repensar de manera holística los conceptos de vulnerabilidad y riesgo. Una crítica y una revisión necesaria para la gestión. *Centro de Estudios Sobre Desastres y Riesgos*, pp. 1–18, 2001.

[2] Albinet, M. & Margat, J., Groundwater pollution vulnerability mapping. *Bulletin du Bureau de Researches Geologicques et Minieres Bull BRGM*, **2**(3), pp. 13–22, 1970.

[3] Zwahlen, F., Vulnerability and risk mapping for the protection of carbonate (karst) aquifers, scope, goal, results. European Commission, COST Action 620, Belgium, 2003.

[4] Ríos-Roja, L. & Vélez-Tálvaro, M., Vulnerabilidad a la contaminación, zona sur Acuífero del Valle del Cauca, Colombia. *Boletín de Ciencias de La Tierra*, **23**, pp. 69–84, 2008.

[5] Aguilar-Duarte, Y., Bautista, F., Mendoza, M., Frausto, O., Ihl, T. & Delgado, C., IVAKY: Índice de la vulnerabilidad del acuífero kárstico Yucateco a la contaminación. *Revista Mexicana de Ingeniería Química*, **15**, pp. 913–933, 2016.

[6] Bolio-Barrientos, E., Bautista, F. & Pacheco-Ávila, J., Uso de la metodología EPIK para determinar la vulnerabilidad del agua subterránea a la contaminación en Yucatán, México. *Revista Teoría y Praxis*, **9**, pp. 55–72, 2011.

[7] Barragán, J.M. & de Andrés, M., Expansión urbana en las áreas litorales de América Latina y Caribe. *Revista de Geografía Norte Grande*, **64**, pp. 129–149, 2016.

[8] Pousa, J., Tosi, L., Kruse, E., Guaraglia, D., Bonardi, M., Rizzetto, F. & Schnack, E., Coastal processes and environmental hazards: The Buenos Aires (Argentina) and Venetian (Italy) littorals. *Journal Environmental Geology*, **51**, pp. 1307–1316, 2007.

[9] Momejian, N., Abou Najm, M., Alameddine, I. & El-Fadel, M., Groundwater vulnerability modeling to assess seawater intrusion: a methodological comparison with geospatial interpolation. *Water Resources Management*, **33**(3), pp. 1039–1052, 2019. DOI: 10.1007/s11269-018-2165-4.

[10] Contreras Tax, A., Frausto Martínez, O. & Uhu Yam, W., Groundwater quality in a karstic zone of the island of Cozumel, Quintana Roo, Mexico. *Tropical and Subtropical Agroecosystems*, **24**(1), 2021. https://www.revista.ccba.uady.mx/ojs/index.php/TSA/article/view/3617Nicholls.
[11] Cazenave, R.A., Sea-level rise and its impact on coastal zones. *Science*, 2010. DOI: 10.1126/science.1185782.
[12] Zhou, Y., Yang, F., Wu, X., Jia, C., Liu, S. & Gao, Y., Bibliometric analysis of research progress on karst groundwater pollution. *IOP Conference Series: Earth and Environmental Science*, **568**(1), 2020. DOI: 10.1088/1755-1315/568/1/012040.
[13] Chachadi, A. & Lobo-Ferreira, J.P., Sea water intrusion vulnerability mapping of aquifers using GALDIT method. *Workshop on Modelling in Hydrogeology: Proceedings*, Anna University, Chennai, India, pp. 143–156, 2001.
[14] Blanco de la Paz, E., Brown-Manrique, O. & Márquez-Gurri, R., Vulnerabilidad a la contaminación de las aguas en la cuenca sur de Ciego de Ávila. *Revista Ingeniería Hidráulica y Ambiental*, **39**(1), pp. 73–83, 2018.
[15] Ruiz-Ramírez, J.D., Gutiérrez-Aguirre, M.A. & Frausto-Martínez, Ó., Biodiversidad y vulnerabilidad de Playa del Carmen ante el incremento del nivel medio del mar. *Handbook T-IX CIERMMI Mujeres en la Ciencia Biología*, ed. O. Vargas-Delgado, pp. 95–106, Mexico, 2020.
[16] Frausto-Martínez, O., Zapi-Salazar, N.A. & Colin-Olivares, O., Identificación de formas kársticas mediante tecnología LiDAR: Isla de Cozumel, México. Tendencias en geomática: una perspectiva de las ciencias de la tierra, IntechOpen, 2018.
[17] Colín-Olivares, O., Frausto-Martínez, O. & Rodríguez, C., Cálculo automatizado de la profundidad de depresiones kársticas a escala detallada. *Conocimientos y saberes del karst tropical en México*, ed. O. Frausto-Martínez, pp. 55–78, 2019.
[18] Rodríguez-Castillo, J.F., Frausto-Martínez, O. & Olivares, O., Morphometry of karst depressions at detailed scale: El Cedral, Cozumel – Mexico. *Tropical and Subtropical Agroecosystems*, **24**(1), 2021.
[19] Fragoso-Servón, P., Bautista, F., Frausto, O. & Pereira, A., Caracterización de las depresiones kársticas (forma, tamaño y densidad) a escala 1:50,000 y sus tipos de inundación en el Estado de Quintana Roo, México. *Revista Mexicana de Ciencias Geológicas*, **31**(1), pp. 127–137, 2014.
[20] Frausto-Martínez, O., Colín-Olivares, O. & Rodríguez-Castillo, J.F., Karst en la ciudad: Planificación del espacio urbanístico de la zona urbana de Cozumel, México. *Revista Agroecosistemas Tropicales y Sub-Tropicales*, **24**(1), p. 31, 2021.
[21] Arnoldus, H., An approximation to the rainfall factor in the universal soil loss equation. *Assessment of Erosion*, eds M. Boodt & D. Gabriels, pp. 127–132, 1980.
[22] UNESCO, Guía metodológica para la elaboración del mapa de zonas áridas, semi-áridas, y sub-húmedas secas de América Latina y el Caribe. CAZALAC. Documentos Técnicos del PHI-LAC, No. 3, 58 pp, 2006.
[23] Carretero, S. & Kruse, E., Impacto de la urbanización en la infiltración en un área costera, Argentina. *Tecnología y Ciencias del Agua*, **5**(6), pp. 5–24, 2014.
[24] Howard, K. & Gerber, R., Impacts of urban areas and urban growth on groundwater in the Great Lakes Basin of North America. *Journal of Great Lakes Research*, **44**(1), pp. 1–13, 2018. DOI: 10.1016/j.jglr.2017.11.012.
[25] Serra, J., Cameira, M.D.R., Cordovil, C.M. & Hutchings, N.J., Development of a groundwater contamination index based on the agricultural hazard and aquifer vulnerability: Application to Portugal. *Science of The Total Environment*, 2021. DOI: 10.1016/j.scitotenv.2021.145032.

[26] Heiß, L., Bouchaou, L., Tadoumant, S. & Reichert, B., Index-based groundwater vulnerability and water quality assessment in the arid region of Tata city (Morocco). *Groundwater for Sustainable Development*, 2020. DOI: 10.1016/j.gsd.2020.100344.
[27] González-Herrera, R.A., Albornoz-Euán, B.S.I., Sánchez, Y., Pinto, I.A. & Osorio Rodríguez, J.H., El Acuífero Yucateco. Análisis del Riesgo de Contaminación con Apoyo De Un Sistema De Información Geográfica. *Revista Internacional de Contaminación Ambiental*, **34**(4), pp. 667–683, 2018. DOI: 10.20937/rica.2018.34.04.09.
[28] Nicholls, R.J., Adapting to sea level rise. coastal and marine hazards, risks, and disasters, 2015.
[29] Bautista-Zuñiga, F. & Aguilar-Duarte, Y., Riesgo de Inundación Ante Lluvias Extremas en el Karst de la Ciudad De Mérida Yucatán México. *Tropical and Subtropical Agroecosystems*, **24**(35), pp. 1–12, 2021.

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MUNICIPAL COASTAL GOVERNANCE IN LATVIA: NON-STATUTORY INSTRUMENTS FOR COLLABORATIVE GOVERNANCE DEVELOPMENT

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ABSTRACT

The article summarizes results from the research and development (R&D) project aimed at the detailed ecological–social–economic (ESE) system based and stakeholders co-guided coastal studies for the methodological instrumentation improvements of the coastal governance practice, being realized by System Approach Framework (SAF) method application. The study was done in the Latvian coastal municipal context, characterized by the lengthy and sparsely populated coastal areas governed by small municipalities with limited institutional and other capacities, lacking coastal knowledge and adequate governance instruments for sustainable integrated coastal management (ICM). Earlier studies show that the majority of coastal municipalities in Latvia face similar challenges. Thus, a generic problem addressed by this study was the lack of the vital coastal governance capacity at local level. The study applied the case study research methodology, which permits complex analysis of the coastal system governance. Complementary to the desk analysis of governance policies, interviews/survey of coastal inhabitants and coastal observations, and use of other social research methods were combined with stakeholder involvement. The study done for a pilot case of Salacgriva municipality demonstrates possibility and instrumental background for establishment of the interface between SAF methodology and coastal municipal development planning approach and practice in Latvia as well as the necessary coastal governance process design and development steps. Building on the basic preconditions for the successful ICM – participation and science-policy interface – a set of innovative non-statutory ICM instruments was designed. Coastal indicators system (IS) was used as a special type of modelling that is understandable by the coastal stakeholders compared to other modelling tools. Other elaborated innovative instruments include multi-thematic municipal coastal monitoring system together with ESE based indicator system; a structure and content of the Coastal Governance Survey and their applications for the coastal thematic planning. All these complementary outcomes provide background for ICM integration in the municipal planning system.

Keywords: coastal indicator system, collaborative governance, governance instruments, stakeholder participation, science-policy interface, system dynamic model, System Approach Framework.

1 INTRODUCTION

Systems Approach Framework (SAF) provides multidisciplinary and trans-disciplinary advice to environmental managers and policymakers concerning environmental problems in the coastal zone, in order to improve coastal sustainability [1]. Accordingly, the SAF shall serve as the tool to translate scientific knowledge and data to policy decisions, in such a way which ensures that knowledge is transferred fully and understandable by stakeholders and practically applicable for decision-making at local level [2]. The SAF contributes to endeavours to elaborate systemic and integrative approaches for coastal sustainability, particularly, integrated coastal management (ICM) [3]–[5].

The general goal of the research and development (R&D) case study was to develop a SAF based coastal governance research application suitable for coastal governance situations in small municipalities of Latvia, and, based on findings – to elaborate policy recommendations and instruments for improved ICM. The goal was supported by several complementary tasks:

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- To apply and demonstrate the transition from separate isolated disciplinary issue orientated research to a comprehensive multi-disciplinary and multi-stakeholder R&D framework for coastal governance process studies and stakeholder participation.
- To establish an interface between SAF methodology and coastal development planning methodology including supervision of designed development documents, i.e. the application of coastal information systems (coastal indicator system, in particular) developed in accordance with SAF methodology.
- To create a set of instruments that could be used to attain better understanding of the coastal system and its governance, while collaborating with stakeholders and among themselves for implementation of coastal activities. Important prerequisite is costal governance efficiency and self-sufficiency, which means low costs and use of available capacities, primarily those of municipal specialists and local stakeholders.
- To identify elements and demonstrate synergy between science research and applications of citizen science for purposes of both, better coastal science and governance in general.

Testing and adaptation of the general SAF methodology for application in the municipal governance sector was based on systemic understanding of the coastal territory as a unified governance territory, where interests of different governance levels interfere. In partnership with local stakeholders, through studying the current state of the coastal ecological–social–economic (ESE) system, and, the state of the governance as its sub-system, the objective of the research was to structure governance processes to identify typical governance approaches (models) and instruments, seeking for synergies between those models and instruments and look for their complementarity opportunities.

2 METHODS AND MATERIAL

The selected case study pilot site – Salacgriva municipality (Latvia) – is located on a 5 to 15 km wide strip of the Baltic Sea coast (the Gulf of Riga) stretching for 55 km, it occupies 638 sq. km with population of 9,000 inhabitants. The municipality is characterized by advanced environmental governance and participatory experience as compared to other municipalities in Latvia. At the same time, there is concern that limited progress in coastal activities may lead to the degradation of the coastal resources and hamper their sustainable use for common benefit. Based on information from desk studies, literature and local stakeholders survey, it was concluded that the success of coastal governance is limited by typical generic problems, namely, limited capacity (human, administrative, financial etc. resources) and a critical lack of reliable and update coastal information, what affects local coastal decision-making.

Steps-wise structured SAF methodology was the main backbone to be applied and studied in detail (Fig. 1). The SAF step of issue identification included: (1) coastal problems and their links to human activities; (2) relationships with ecosystem services; (3) DPSIR and CATWOE tools based analysis of coastal territory; (4) identification and involvement of stakeholders; (5) institutional mapping; and (6) identification of principal ecological–social–economic (ESE) components relevant for assessment of the state of coast.

During the step of system design, the relevant coastal area geographical boundaries and boundaries for coastal data areas have been defined. Descriptions of elements, material flows, and external hazards within the coastal ESE subsystems, including governance subsystem was done. A system dynamic model (SDM) has been developed, followed by its translation into STELLA language [6].

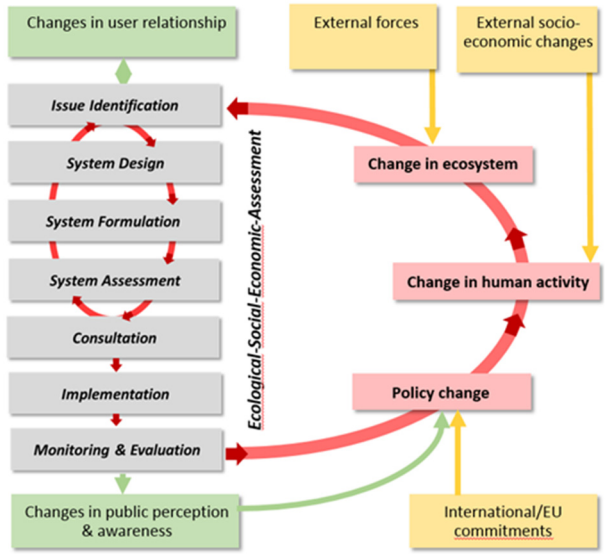

Figure 1: SAF steps. *(Source: BaltCoast project, www.baltcoast.eu.)*

The SDM analysis completed our understanding on the ongoing natural (ecological) and socio-economic processes in the typical coastal areas and their interaction, and lead to understanding the necessary framework for the science policy (decision-making) interface. It brought to the optimal number of parameters (necessary and sufficient) to characterise the state of the coast. Crucially, the indicator system is both – an information flow system and a modelling tool, which is assumed to be understood by the stakeholders, because the trends in indicator values make it possible to project future coastal scenarios [7].

Implementation of system formulation and appraisal steps focused on transition from the research stage (SDM stage) to the governance stage – a practical improvement of the coastal governance by proposing CIS approach. The transition was based on the following principles:

- Evaluating the dynamism of SDM parameters and including additional parameters with sufficient dynamics in the CIS;
- Evaluating regular, reliable data applicable to the coastal area, based on public data or applying other direct methods for obtaining data, including elements of citizen science;
- Including indicators which provide the link to the key municipal planning documents in short-, medium- and long-term perspective: sustainable development (SD) strategy, development programme, and investment plan;
- Evaluating the necessity for additional indicators to characterise the coastal SES in a more detailed manner, based on SD capitals approach.

Implementation and monitoring steps focused on development of the CIS implementation accordingly the completion level of the CIS: either it is full/complete CIS; or partial CIS; also for pilot implementation of some indicators and stepwise extension of indicators. The proposal for CIS was prepared for the pilot case of Salacgriva municipality with view to its eventual application for the whole eastern coast of the Gulf of Riga (for the Vidzeme region).

Institutional mapping and stakeholder engagement steps revealed over 130 institutions and stakeholders involved or with potential interest in the coastal governance (Fig. 2).

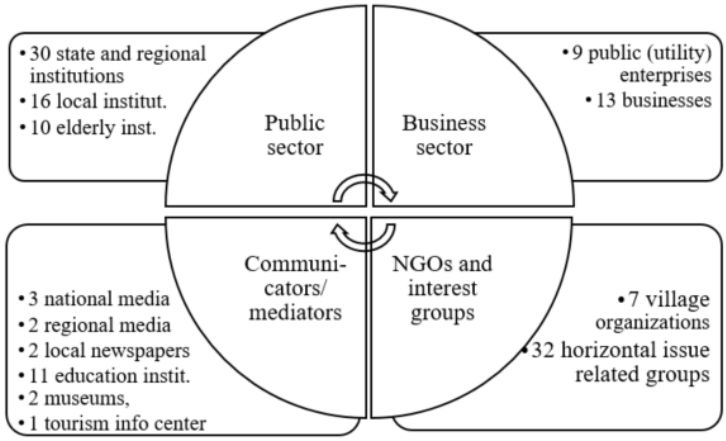

Figure 2: Institutional mapping of coastal stakeholders.

3 RESULTS

3.1 Understanding of the coastal issues and relationships to the ecosystem services

As result of the desk studies, thematic focus groups and stakeholder involvement, a list of 19 problems were identified in the coastal territory of Salacgriva municipality**.** Their analysis brought to the following principal findings: (1) there are few local coastal territories where resources are overly exploited or used in the interests of a limited group of stakeholders or individuals, creating additional strain on resources, as well as environmental pollution, as well as discomfort among other stakeholders. (2) At the same time, there are also local coastal territories where coastal resources are under-managed, causing risks of their further degradation.

The following causes of insufficient management were identified: (1) low density population of the coastal territory cannot provide a basis for sustainable coastal management, (2) stakeholders (including municipal authorities) insufficiently understand potential of the coastal resources for their local development; (3) lack of reliable information to support sustainable use of coastal resource for local development; (4) insufficient municipal efforts and activities for ensuring adequate coastal management.

A matrix of relationships between identified problems was prepared, revealing links that were scored as follows: 3 – direct, explicit link; 2 – direct, less explicit link; 1 – indirect link; 0 – unclear link (Table 1). Analysis of the problems structure and their interconnections led to the conclusion that there are three generic problems: (1) insufficient managed low-density coastal territories, (2) insufficient local environmental management/governance capacity, and (3) limited coastal communication (highest sored problems no. 17–19). Each coastal problem was analysed in respect to its relation towards providing ecosystem services.

3.2 Design of the virtual system

The next SAF step was to develop a conceptual system model for the central issue of the overall coastal governance system which was defined as “Unsustainable governance of coastal resources”. During the design of conceptual system model it was necessary to answer:

Table 1: Problems relationships with ecosystem services.

Nr.	Problem\Services group	Prod.	Regul.	Val.	Func.	Total
1.	Restricted access to sea	2	0	3	0	5
2.	Coastal erosion/dune existence	1	2	3	3	9
3.	Access of coast for people with special needs	0	1	3	0	4
4.	Coast erosion/shoreline preservation	1	3	2	3	9
5.	Over flooding during storms/areas with minimized risk of flooding	2	2	0	1	5
6.	Risks to valuable biotopes/the existence of valuable habitats	1	3	2	3	9
7.	Sea water quality	1	1	3	1	6
8.	Human safety in bathing/swimming places	0	0	3	0	3
9.	Nutrients pollution from rivers/ensuring the quality of water in rivers and on the coast	3	3	0	2	8
10.	Indvidual households' wastwaters/ensuring the quality of water in rivers and on the coast	3	3	0	3	9
11.	Potential pollution form industrial sites/industrial territories with (at least) no increase in the amount of pollution	0	2	1	1	4
12.	Forest damage/the existence of high-quality forest ecosystems	3	2	3	3	11
13.	Marine litter/unpolluted coastal assurance	1	3	3	1	8
14.	Risks to nature and culture capital/natural and cultural heritage of the existence of high quality	2	0	3	1	6
15.	High local seasonal pressures/providing minimally polluted coastal zone in sezonality visiting periods	2	2	3	1	8
16.	Construction of residential buildings on coast\dune existence	1	2	3	1	7
17.	Insufficiently managed low density territories	2	1	3	2	8
18.	Low environmental management/governance capacity	1	3	2	3	9
19.	Limited coastal communication/the existence of coastal communication	3	1	2	2	8
	Service group involvement	29	34	42	31	136
	The share of service group	21%	25%	31%	23%	100%

- What are coastal resources comprised of? The approach was based on three principal environmental management goals: protection of coastal biological diversity, ensuring coastal environmental quality and sustainable use of coastal natural resources.
- Which are system components? Governance subsystem, added to SES, became a central block allowing to address the central issue.
- Flow conceptualization was based on assessing pollution as a direct physical impact: ascertaining whether flow impact is negative or positive towards particular element.
- "Environmental action models" as a factor which influences system's behaviour was placed at the centre of the model. Such approach allowed to created links between: (i) environmental governance and municipal local governance instruments, (ii) stakeholder groups representing local socio-economic system, (iii) the application of specific governance models and instruments influencing stakeholders and encouraging them to adopt preferable environmental/coastal friendly activities. As result, (iv) this has a positive direct impact on reducing pollution and resource depletion in the coastal area.
- Impacts of external subsystems affect: (i) local economic activities, (ii) social system, the central element of which, in this model, are households and their practices or environmental/coastal activities, (iii) marine litter as global emerging problem affecting the coastline, (iv) external natural system (climate change which impacts seen as the erosion of dune ecosystem and wider coastal areas (forests, meadows), (v) blooming algae causing direct social and economic impacts (loss of property value, impacts on seasonal visitors etc.), (vi) invasive species (appearing due to climate change and human activities (e.g. shipping), besides deteriorating the coastal quality that results in limited open clean coastal space suitable for visitors.

Answering those questions in a systemic manner, enabled the research team to establish a coastal virtual system model for nature and governance subsystems.

3.3 Description of ESE model using indicator system approach

Thus, the main objective of the further SAF work was to make the transition from the research phase (development, modelling and analysis) to the improvement of coastal governance in practice. To achieve this, taking the SDM as the base, practically applicable tools for the coastal area governance were developed. An overall approach for attaining the system of coastal governance tools to address the issue applying the SAF is illustrated in Fig. 3.

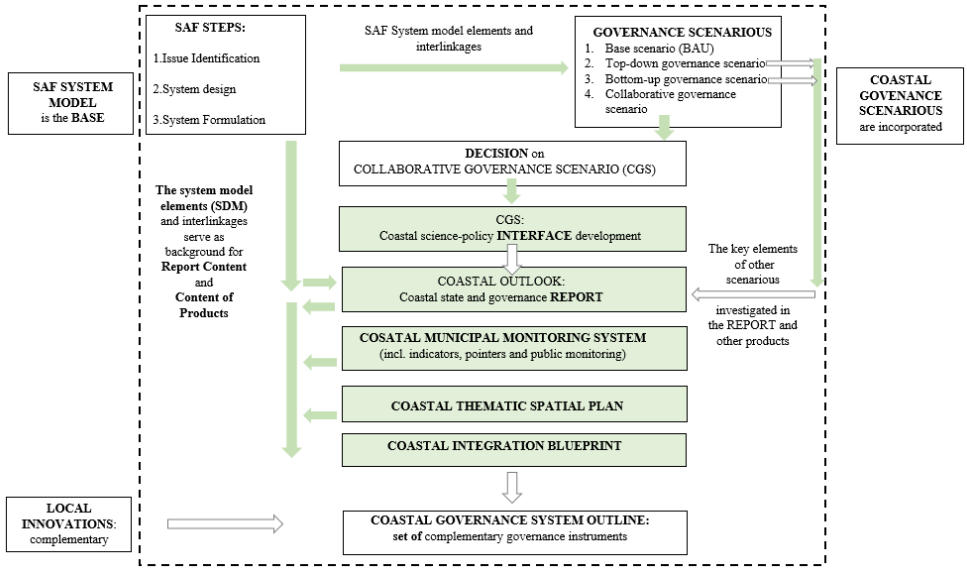

Figure 3: Layout of SAF application for coastal governance case [7].

The SDM makes it possible to establish an optimal number of parameters (necessary and sufficient) to characterise the state of the coast as a subject of municipal governance, and in particular, to understand the natural (ecological) and socio-economic processes and their interaction and framework for establishing interface to link science and decision-making.

The CIS is an important coastal governance decision-making support tools [8]. To establish a clear transition from the SDM model (science model) to the indicator system (IS) as a decision-making tool the following development steps have to be taken. Firstly, we had to look at the systemic parameters of the SDM. These parameters are required to understand SDM. The input parameters define initial conditions for further analysis of the state of the coast. At first, the parameters have been analysed from the point of their dynamic for change. The parameters with significant dynamics for change have been further included in the list of the coastal sustainability indicators.

As the whole complex system, CIS:

- describes the state of the coastal area, the stability of both – the coastal ecosystem and the coastal ESE, and their restorative potential;

- presents stakeholder concerns through the key parameters which can be improved through stakeholder participation in collaborative governance scenario [9].
- the set of indicators, included in CIS, are necessary and sufficient to adequately represent the functionality of the coastal system and the impacts of actions performed in the coastal area. These can produce a reliable view of the state and dynamics of coastal and governance, to possible extent considering limitations and conditions. This reasonability is provided by both – the CIS structure and methods chosen for data collection, processing, and analysis.

A proposed monitoring system includes parameters of different governance needs/levels: (i) quantitative indicators for monitoring long-term processes; (ii) quantitative resultative pointers characterising the achievement of objectives; (iii) semi-quantitative parameters: ranged observations and (iv) resultative pointers – a checklist (Yes/No).

There are three governance levels for application of the CIS:

- Strategic level – full-scale CIS application with biannual measurements for highly dynamic indicators and at least every five year measurements for indicators with lower dynamic. The main obstacles for implementing are costs and human resources.
- Tactical level – short-term annual monitoring measuring indicators which are highly relevant to characterize change in the coastal area. The costs of measurements shall be reasonable and carried out by either a municipal specialist or local communities or both. This monitoring shall be linked to the actual municipal development targets.
- Operative level – seasonal/monthly observation of the processes in critical coastal areas. The obtained data should be efficiently processed and analysed, and based on it – operative coastal management decisions should be taken and implemented in due time.

The CIS and the related Municipal Coastal Monitoring Programme (MCMP) are based on:

- Modifying and making better use of an existing component – municipal institutions' capacities, better organisation of the assessment of parameters;
- Additional new component – new bottom-up initiatives of stakeholders organized in coordinated and complementary way. Based on scientific research methods and citizen science initiatives, a citizen monitoring system has been designed;
- Integration of this new component and optimisation of the existing component will lead to the development of a new approach for assessment and new governance decisions.

The application of the CIS and MCMP have also been evaluated on the basis of the general governance scenarios developed within the previous SAF step [10].

In other words, the following information have been ascertained:

- What data has been collected and for which specific indicators (BAU scenario);
- What additional data might be collected by municipal institutions (top-down approach);
- Which data collections stakeholders are interested in (bottom-up approach);
- What collaboration should be established among municipal authorities and stakeholders and what new added value this provides (in the context of a collaborative scenario).

3.4 Use of indicators for assessment of ecosystem services

The developed MCMP indicators and parameters was connected to ecosystem services/ functions).

Assessment provided in Table 2 indicates that generally the indicator system is oriented to the assessment of a production function of the ecosystems.

Table 2: Links between CIS indicators and ecosystem functions.

Ecosystem services/functions	Number of indicators ranked "2"	Number of indicators ranked "1"	Total number of indicators
Production	9	25	43
Regulation	3	12	18
Cultural values	4	23	31
Support	9	3	21
Total number of indicators	25	63	–

Legend: Value "2" – if the indicator makes it possible to evaluate ecosystem, function, "1" – if the indicator provides indirect information for evaluation.

4 DISCUSSION

The novelty of the SAF application was the conceptual invention of a coastal science-policy interface for municipal governance case, which means integrated preparation of scientific knowledge that could subsequently be translated, transferred and integrated into ICM-related decision-making and implementation practice at the local level. This requires elaboration of the required background and tools for both the transfer process and deliverables, in order to manage interpretation of scientific data into "language" understandable by decision-makers at all governance levels, but primarily at local level and by the general public.

At first, the challenge for local governance and the first element and step of interface is coastal multi-thematic research and development and support for results, as the initial scientific basis for ICM development. Natural and social sciences knowledge of the land–sea interaction is available from academic and applied studies, but there is still a lack of locally specific coastal data and knowledge.

The second interface element is a Coastal Governance Survey (CGS). This is an informative and analytical document, which serves as a basis for policy formulation and decision-making. The CGS concept provides for the assessment of the state of ESE, including governance, particularly assessing instruments (Table 3), and role of stakeholder groups and their involvement in governance.

As regards the third interface element, the most important socio-natural process and impact parameters and its system are transformed within the framework of CGS content and the process that is a backbone of the coastal governance assessment system to be designed and applied for subsequent governance cycles – including the municipal coastal monitoring system (MCMS), but later also as a coastal indicator system, which are complementary and developed accordingly. MCMS is a complex observation (monitoring) system of different parameters, which makes it possible to judge both the implementation of spatial planning document (primarily, local SD strategy), and the general situation concerning the sustainability and sustainable governance within the municipal (and coastal) territory. It is designed for long-term planning documents. Information obtained from monitoring has to be used in formulation of policies and new planning documents; as well as directly for decision-making.

Table 3: Coastal governance instruments.

Instrument groups	Practical realization of governance instruments
Planning instruments	• Coastal problematics integration in planning (SD programme, spatial plan, development programme), integration monitoring; • Coastal sustainability report (present situation assessment); • Coastal thematic plan; • Coastal problem areas/sectors detail plans/local plan; • Coastal municipalities indicator system and monitoring.
Legislative instruments	• Local regulations specific to the coastal management; • Local regulations for communal services use (incl. for visitors).
Policy instruments	• Coastal (or environmental) consultative board at the Council; • Coastal sustainability/green declaration; • Commitments by the Council (like the Mayors' Climate Pact); • Municipality's sustainability report.
Economic and financial instruments	• Penalties, discounts for coastal management activities; • Entrance fees/permits (also outside the beach zone); • Project support (from LEADER and other programmes); • Environmental/coastal budget as a chapter in municipal budget.
Infrastructure instruments	• Parking places and access roads; • Footbridges/paths; nature trails and watching towers/platforms; • Information signs/instructions/boards; • Summer piers/boat docks, other boats management solutions; • Solutions for fortification of coastal dunes ecosystems; • Alternative energy (solar, wind) generators to lit nature trails.
Organizational (institutional and administrative) instruments	• Coastal (environmental) management commission/committee; • Coastal monitoring and management staff (seasonally); • Coastal development and infrastructure planner/manager; • Coastal NGO villages associations/elders with delegated tasks.
Communication instruments	• Coastal state monitoring (incl. citizen science); • Coastal topics in all education levels' curricula and projects; • Coastal citizen science mobile app and educational brochure; • Institutional internet site section devoted to the ICM.

MCMS is based on different types of applied coastal monitoring measures implemented by:

- Local municipality administration and subordinated organizations/services' staff;
- Other organisations, to whom certain municipal management functions are delegated;
- Interested inhabitants/groups and their representatives, thus potentially providing public participation contribution (citizen science), and
- Supplementing it with expert studies/assessments when necessary.

The citizen science contributes through public monitoring development involving self-organizing potential of networking between different voluntary groups/individuals [11]. As far as possible, this should be based on science principles. The general approaches have to be elaborated by relevant experts and discussed with stakeholders, while the public

monitoring programme should be supplemented with the parameters characterising the performance of the municipal medium-term development programme. Given the significant contribution from public involvement, a decision must be supplemented with a type of collaborative governance mechanisms. It could be a written agreement between municipality (or other public institutions) and NGOs, also with Eco-schools and other interest groups regarding the commitments for public monitoring.

The fourth challenge is the development and application of a municipal coastal (and development) indicators system (CIS/IS). In general, indicators are a tool for organising information and defining priorities. The IS simultaneously provides input for both ICM done by the municipality, as well as the assessment and achievement of strategic development goals. Assessment of indicator values is conducted by the municipality based on a precisely elaborated system of algorithms.

The fifth interface element and development step is the design of a coastal planning instrument – Coastal Governance Thematic Plan (CGP) which means implementation of a disciplinary ICM approach. Such a thematic plan should be an important component of the mandatory municipal spatial planning, providing a higher level spatial resolution and detailing (using spatial zoning approach) of the coastal territory.

The sixth and decisive step of the coastal governance interface is the result of all the previously developed scientific-applied results, integration into municipality mandatory development planning documents and budget (financial and investment plans). It is equally important that similar integration occur in connection with other existing or potential voluntary planning documents. Such integration process and result would ensure better vertical integration between national and local coastal development practices.

It is important to note that, throughout the BaltCoast project, the Latvian research team has considered development of Coastal Indicators System (CIS) as a special type of modelling The way research team interpreted quantitative modelling which actually might be either the mathematical modelling or modelling by applying CIS, is the CIS based on quantitative values and maintaining stakeholders' involvement in its definition. Taking this as a basic premise, a methodology was developed by the Latvian research team to ensure/create an interface for the transition from conceptual SDM to CIS-based modelling. The participatory function is undoubtedly a backbone of the SAF. CIS sustains the participatory function. Analytical models of the SAF methodology (especially CATWOE) provide new opportunities for identification and grouping of stakeholders.

5 CONCLUSIONS

Generic and typical ICM problems faced by many rural coastal municipalities in Latvia, which essentially lack the most vital local coastal governance capacities, require different management solutions to those traditionally and statutory-based being used already to approach topical problematic coastal issues as expounded in SAF applications and in the case studies of the BaltCoast project partners.

Therefore, besides basic development of the SAF application and its adaptation for coastal governance process, the following tasks were specifically assigned for the Latvia case study:

- To explore and evaluate different municipality coastal governance (ICM) approaches and
- To elaborate necessary approaches for SAF and ICM integration into the general local decision-making and municipal developmental/spatial planning.

The case study demonstrates the establishment of the interface between SAF methodology and coastal and municipal development planning methodology, leading to the development

of new coastal governance instruments in Latvia and their introduction, proposals for coastal analysis and governance, as well as integration proposals for general municipal planning.

The study area – Salacgriva municipality is also characterised by experience in environmental and participatory governance that is among the most advanced in Latvia, including village development-oriented NGOs, Village Elders institution, stakeholder Advisory Councils which taken together have an impact on formal local decision-making. At the same time, there is limited progress in the coastal development. The stakeholders are concerned about coastal resources which are not sufficiently protected and ongoing coastal degradation that may negatively affect the use and sustainability of the coastal resources for common benefit.

Thus, a type of generic problem limits the success of coastal governance in the municipality and this is seen as limited human, administrative, financial and other resources available for coastal governance. Another critical obstacle to the local coastal governance is the lack of reliable and update coastal information, resulting in flawed understanding of ongoing processes in the coastal area, which, in turn, undermines decision-making.

Applying SAF methodology, in particular, by using the SES and the stakeholder participation approaches, a coastal governance interface with ICM instruments was developed for the pilot territory. Importantly, all products are innovations for ICM in the national/Latvian context.

Science policy interface framework elaborated for the coastal (ICM) policy development, includes the following four innovative complementary set of non-statutory key ICM instruments:

- Municipal Coastal Collaborative Monitoring System (ICM Monitor) – a multi-disciplinary and public engaged (citizen science) programme for regular and locally managed provision of actual and locally managed information and also to be used for the ICM Outlook update with 2–4 years' regularity;
- Coastal Indicator System (CIS) as SAF application model for governance practice and Public Coastal Monitoring Programme (incl. detailed multi-thematic coastal monitoring for whole 55 km long coastline) as the complementary parts of the ICM Monitor.
- Municipal Coastal Governance Outlook (ICM Outlook) – a coastal status and governance Source Book/Report, based on multi-thematic data form national–regional–local level information (including necessary horizontal and vertical integration) and a special ICM studies/monitoring overview compiled locally for the municipal coastal area as a complex ESE system to be used for any ICM sector development and other related sector decision-making/planning at local municipal level with the participation of all stakeholders;
- Coastal Integration Blueprint (ICM Integration) – guidelines for the ICM approach and science-policy interface instruments, e.g. the coastal data/monitoring/procedures, integration into both mandatory and voluntary municipal planning process/documents: the municipal development programme (for a seven-year period with an annual upgrade) and related Spatial Plan.

Improvement of the coastal governance is based on modifying and better use of existing governance components: existing municipal institutional capacity (and staff) and providing space for non-statutory, new bottom-up initiatives by the stakeholders. Integrating these two components will lead to the establishment of a new approach for assessment of the state of the coastal area and new governance decisions inspired by it.

Overall, the application of SAF methodology and adaptation of it to the coastal governance R&D case in Latvia within the pilot study site in the Salacgriva municipality has

facilitated novel application of the SAF methodology; building of a new collaborative governance model and tools; creation of an interface between science and policy (decision-making), as well as practice (society); and conceptualisation of the coastal monitoring programme as an essential tool for collaborative governance that is aimed at improved ICM and is based on local ownership and active public(citizen) involvement.

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REFERENCES

[1] Hopkins, S.T., Bailly, D., Elmgren, R., Glegg, G., Sandberg, A. & Støttrup, J.G., A systems approach framework for the transition to SD: potential value based on coastal experiments. *Ecology and Society*, **17**(3), p. 39, 2012.

[2] Stottrup, J.G., Dinenses, G.E., Holder, J., Gillgren, C. & Schernewski, G., Re-visiting ICM theory and practice: lessons learned from the Baltic Sea Region. *Ocean and Coastal Management*, **139**, pp. 64–76, 2017.

[3] Atkinson, R. & Klausen, J.E., Understanding sustainability policy: Governance, knowledge and integration. *Journal of Environmental Policy and Planning*, **13**(3), pp. 231–251, 2011.

[4] Van Kerkhoff, L., Integrated research: Concepts of connection in environmental science and policy. *Environmental Science and Policy*, **8**, pp. 452–463, 2005.

[5] Mattor, K., Betsill, M., Huayhuaca, Ch., Huber-Stearns, H., Jedd, T., Sternlieb, F., Bixler, P., Luizza, M. & Cheng, A.S., Transdisciplinary research on environmental governance: A view from the inside. *Environmental Science and Policy*, **42**, pp. 90–100, 2014.

[6] Richmond, B., STELLA: Software for bringing system dynamics to the other. *System Dynamics Society International Conference*, Keystone, USA, pp. 706–718, 1985.

[7] Ernšteins, R., Kudrenickis, I., Lontone-Ieviņa, A., Kaulins, J. & Urtāns, A., Municipal sustainable coastal governance: Participatory approaches for system analysis and for local monitoring development. *WSEAS Transactions on Environment and Development*, **13**, pp. 276–290, 2017.

[8] Kudrenickis, I., Ernsteins, R. & Kaulins, J., Sustainable coastal science-policy-practice interface development: municipal coastal governance indicator system. *Journal of Environmental Science*, **1**, pp. 255–264, 2016.

[9] Lagzdina, E., Kudrenickis, I., Ernšteins, R. & Lontone, A., Municipal coastal governance towards rural community resilience development: scenarios and tools. *WIT Transactions on Ecology and the Environment,* vol. 226, WIT Press: Southampton and Boston, pp. 297–309, 2018.

[10] Lagzdina, E., Kudrenickis, I., Ernsteins, R. & Kaulins, J., Coastal sustainable development studies in Latvia: Integrated local social-ecological systems governance. *Journal of Social Sciences: Regional Formation and Development Studies,* **1**(21), pp. 68–82, 2017.

[11] Lontone, A. et al., Local coastal governance: Science-policy interface and municipal monitoring. *Proceedings of the 13th MEDCOAST Congress on Coastal and Marine Sciences, Engineering, Management*, Mallieha, Malta, **1**, pp. 105–116, 2017.

SECTION 9
WASTE MANAGEMENT

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MUNICIPAL SOLID WASTE GENERATION: AN EXPLORATORY ANALYSIS OF CONSUMPTION PATTERNS IN PERU

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ABSTRACT

Peru, a developing country, is experiencing an exponential increase in the municipal solid waste (MSW) generation due to population growth and disorderly territorial expansion in urban and rural areas. Most of these settlements do not have proper waste management, which causes contamination in various sectors: health, economy, environment (e.g., soil contamination, informal landfills), among others. Thus, this growth phenomenon can be explained through the consumption patterns of the population, especially those related to the household. To this end, this research seeks to contribute to the MSW management through an exploratory analysis using resources provided by public and non-governmental organizations. In this way, a national database was constructed that reflects consumption trends, characteristics, preferences and significant differences between rural and urban areas. It is expected that this information will contribute to the implementation of management tools that are better adjusted to reality in order to reduce the negative impacts generated by inadequate solid waste management.
Keywords: consumption patterns, households, national panel data, Peru, solid waste management.

1 INTRODUCTION

In a developing country such as Peru, a constant population growth resulting from seeking an improvement in life quality [1] brings with it a change in consumption preferences that causes an increase in the municipal solid waste (MSW) generation [2]. Such an increase is of concern since global solid waste generation levels reached approximately 1.3 billion metric tons in 2012 and an estimated total of 2.2 billion metric tons generated by 2025 [3]. Moreover, if we talk about the overall average composition of waste in the last 10 years, it consists mainly of organic waste (51%), followed by paper (14.1%), plastic (10.4%), glass (4.1%), metals (3.3%) and other materials accounting for 17% of the total volume [3]. However, Peru is no exception to these statistics, since in 2017 on average 58% of MSW was organic. This means that an important part of pollutant emissions can be directly linked to food loss and waste management, due to the fact that average temperature and rain decompose waste increasing pollution and carbon storage rates [4]. In addition, it is considered that the final disposal of MSW is the part of the process with the most shortcomings, since a large part of the MSW is disposed of improperly or is not part of the solid waste management system [5]. It should be noted that in order to address this problem, effective waste management practices must be in place, and for this it is important to be aware of their limitations. For example, the lack of data represents one of the most important restrictions to implement management actions [4], without neglecting other factors (i.e., social, economic and environmental) that can modify the waste generation trend [2].

In recent years, research has been conducted on the impacts generated by the increase in solid waste generation in Latin America [1]. The results of these investigations show an annual rate increase of 2–3% in MSW generation [6] mainly due to two factors that alter consumption patterns: population growth and increased purchasing power [5]. It should be noted that there will be variations in consumption trends if this population growth is greater [7] and even worse if there is no planning or management strategy [8]. This is due to the fact

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that, if the population increases in a disorderly manner, municipalities will not be able to cope due to the poor projection of resources to be used. For example, in marginal areas, where the most impoverished groups of the population live in precarious housing and with reduced spaces, they have low coverage of basic services, thus acquiring diseases associated with water contamination and/or accumulation of waste [8]. In this regard, Peru in the last 10 years, due to the 5% growth of urban population between 2010 and 2020 [9] experienced variations in consumption levels that resulted in a substantial increase in MSW, higher rate of environmental pollution and deterioration of surrounding natural resources [10].

During the last 10 years, the focus on solid waste management was only on cleaning to keep the city looking good; however, today the perspective is different, as an integrated management system that recognizes even more the potential value contained in waste is being contemplated [11]. On the other hand, although the management of MSW generation in other countries has proven to be efficient, the results on which they are based cannot be directly compared or applied at the national level, since there are fundamental differences at the economic, social and political levels [12] that are evidenced by changes in preferences and consumption trends [3]. Nevertheless, the information obtained can help us to project possible scenarios, allowing us to relate socioeconomic strata with consumption trends [2].

Therefore, in order to achieve sustainable management, it is necessary to incorporate national strategies for proper waste management. However, in order to design this action plan, it is essential to know the composition and limitations of the waste generated. For example, the availability of reliable and quality information is an influential factor in this type of analysis. Also, it is essential that the data found include the essential characteristics of the target population (e.g., consumption preferences, urban or rural household, etc.) [1]. Finally, although the information may exist, access to it is not as easy [13], [14]. Therefore, knowing the behavior at the level of preferences and consumption trends that allow understanding the MSW generation is fundamental, in order to contribute to an integrated management, providing strategies for its mitigation [2].

2 CONSUMPTION PATTERNS: CROSS-SECTIONAL ANALYSIS

In the last census of 2017, Peru had 31,237,385 inhabitants, which can be divided under location criteria: urban area (24,771,246 inhabitants) and rural area (6,466,139 inhabitants) [15]. According to INEI (2018) the average trend, both increase for urban and decrease for rural, is 0.19% [16]. On the other hand, the Ministry of Environment (MINAM) observed an average increase of 16.67% in the total annual trend of solid waste generation at the municipal level [17]. The increase in MSW evidenced in Fig. 1 can be explained through an understanding of variations in the inhabitants' consumption patterns [2]. To better understand this term, the Integral Plan for the Environmental Management of Solid Waste in the Province of Lima 2015–2025 defines consumption patterns as the acquisition of products per person in a given time [18]. It should be added that these patterns depend on demographic, social, economic and cultural factors [19]. An example for better understanding is that in places with high economic development, housing rent is a representative expenditure in households, which causes differences in solid waste generation between different regions, as it affects the real purchasing power of households [2].

This indicates that those who consume many resources produce a greater amount of waste as opposed to others who consume few resources. Therefore, these variations in consumption patterns produce changes in the amount and type of solid waste generated [20]. However, there is currently a lack of commitment in the participation of most people regarding MSW generation, so it is necessary to contribute to the sustainable development of waste [21] and

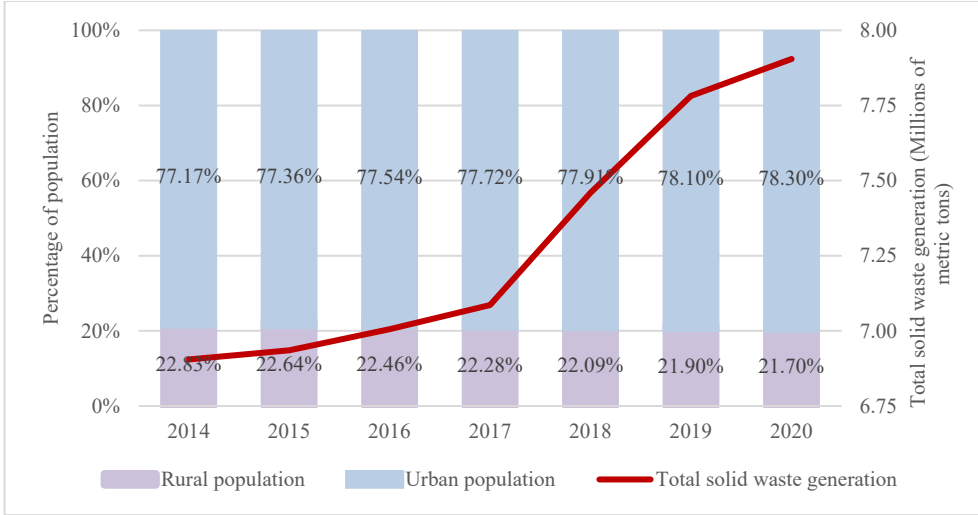
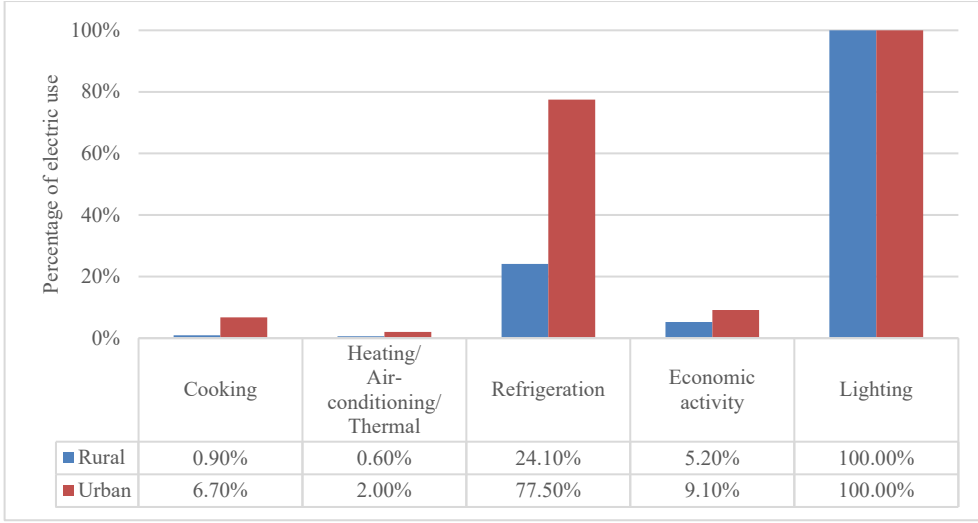


Figure 1: Percentage of urban and rural population and trend of MSW generation in Peru 2014–2020. *(Source: Adapted from INEI [16] and MINAM [17].)*

to adopt optimizations in the approach and development of management strategies [2]. These changes must be permanent and based on the adequate use of natural resources, so that new generations can have better opportunities to use these resources [21].

2.1 Household aspects

Regarding the household aspects, a clear distinction in the levels of expenditure between urban and rural households was evidenced; it is also considered useful to point out that between 2010 and 2020 there has been a 5% growth in the urban population [9]. This increase could be related to the variation in MSW generation rates. As a sample of the aforementioned, energy expenditure in rural households was significantly lower than in urban households, due to the lower purchasing power. On the other hand, there is also a clear distinction in the ownership of household appliances: while in urban households the use of appliances for activities not necessarily related to cooking is more frequent, such as air conditioning among others; in rural households the use of household appliances is specifically intended for this function [22]. Similarly, at the level of expenditures generated in urban vs rural households, it was found that households in urban areas have a higher average monthly expenditure compared to rural households; thus, during the year 2020, Lima, a department with a greater presence of urban households, had an average monthly expenditure of $210.00 in contrast to what was recorded in Puno with an average monthly expenditure of $110.00 [9]. Therefore, it is particularly necessary to analyze the most frequent activities in Peruvian households in order to understand the consumption patterns and which characteristics generate the greatest distinction in terms of municipal solid waste generation [23]. In this regard, Fig. 2 shows the percentage distribution of electricity use according to urban and rural population between 2019 and 2020 [22].



	Cooking	Heating/ Air-conditioning/ Thermal	Refrigeration	Economic activity	Lighting
Rural	0.90%	0.60%	24.10%	5.20%	100.00%
Urban	6.70%	2.00%	77.50%	9.10%	100.00%

Figure 2: Percentage of electricity use distribution according to urban and rural population 2019–2020. *(Source: Adapted from OSINERGMIN [22].)*

2.2 Daily activities

According to the literature review, the activities carried out within the household do have an impact on the MSW generation, for example, in relation to fuel consumption, low-income households focus their electricity and energy consumption only on basic activities such as lighting and refrigeration, while non-poor households also have a more diverse range of consumption, for example, the use of other appliances such as dryers, heating, chargers, washing machines, among others [22]. Likewise, in relation to economic activities as a source of income in Peruvian households, the most frequent in Peru are tourism, livestock, agriculture, and fishing, among others, as well as families whose economic livelihood is based on the fact that household members pursue technical or professional careers [24]. This information is related to waste generation patterns since in the case of MSW generation in rural areas these have a greater participation of the inhabitants in relation to their economic activity while in urban areas they are more related to activities related to food consumption [25].

2.3 Urban and rural settlements

According to geographic location, the classification of households in Peru is divided into urban households belonging to a population center with 2,000 and more inhabitants and rural households belonging to a population center with 500 to 2,000 inhabitants [15]. Now when talking about the factors that affect waste generation rates, in addition to factors such as: lifestyles and economic activities, it is believed that one of the most important factors are food habits, culture, climate and occupation of the inhabitants [26]. In that sense, with respect to socioeconomic conditions, it is observed that there are differences in the level of expenditure related to the economic condition, since it was evidenced that the expenditure made in the household is proportional to its level of income [23]. On the other hand, the number of people in the household has decreased during the period 2007–2017, since the

average number of household members went from 4 to 3.5 in urban households and in rural households from 4 to 3.2 [15]. In that sense, Fig. 3 shows the differences between the monthly consumption (in thousands of sol (S/)) of the urban and rural population by department between 2019 and 2020 of electricity and fuels used for cooking (LPG) and vehicular and motorized use (NGV, gasoline, 90 and 84 octane gasohol) [23].

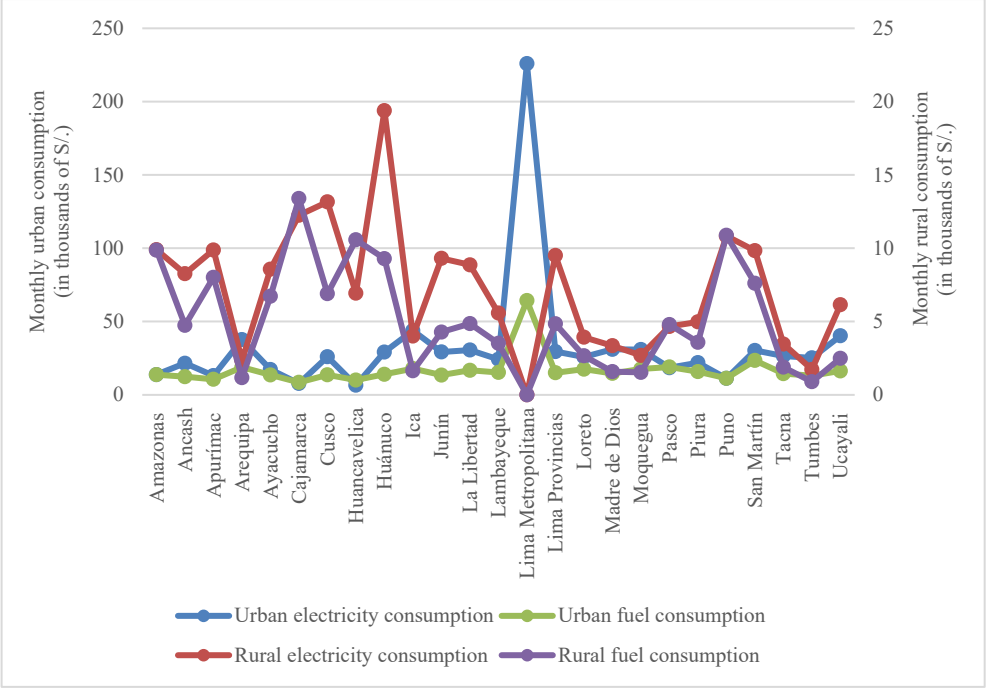


Figure 3: Monthly household fuel and electricity consumption by urban and rural population by department between 2019 and 2020. *(Source: Adapted from OSINERGMIN [23].)*

2.4 Fuels and energy

Research on the relationship between the use of fuel for cooking and the generation of solid waste is scarce. Consequently, for the analysis of fuel consumption trends, it is essential to know the differences in relation to their geographic location. In 2020, the monthly electricity expenditure of households in rural areas was S/ 13, and at the national level, S/ 58 [22]. Now if we talk about the main fuel used for cooking food in Peru in 2020, this was LPG, since it is used in approximately 74% of households. However, there was also evidence of a differentiation in the main use of fuel sources in relation to urban and rural households. For example, firewood represented a significant percentage of use in rural households 45%, while in urban households LPG registered a marked preference, with 81% [27]. In this regard, Fig. 4 shows the percentage of energy used for cooking in the home according to urban and rural population between 2019 and 2020 [22].

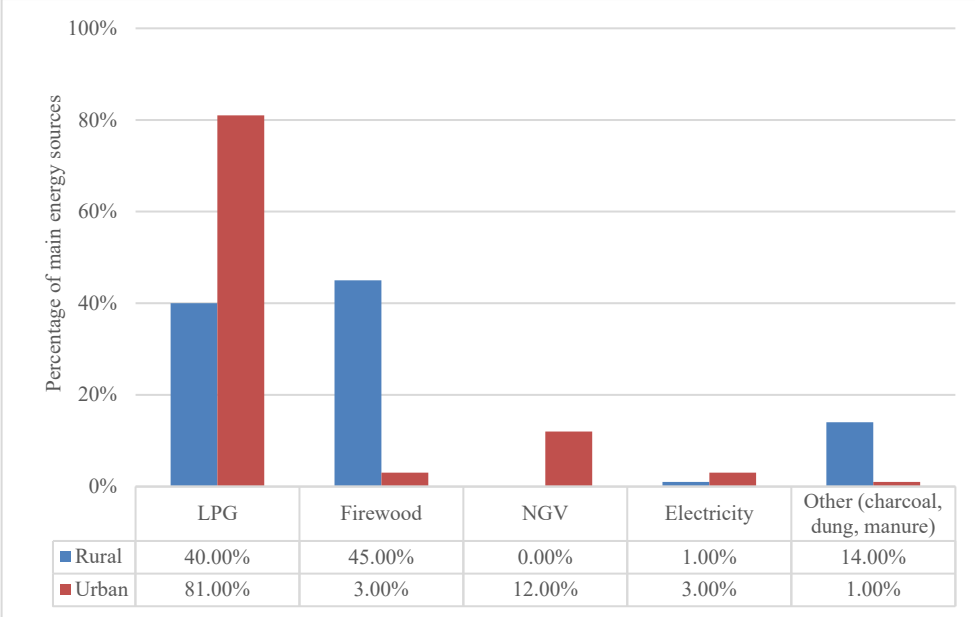


Figure 4: Percentage of energy sources used for household cooking according to urban and rural population 2019–2020. *(Source: Adapted from OSINERGMIN [22].)*

3 DISCUSSION AND MAIN FINDINGS

In relation to the results obtained in different countries with similar characteristics, it should be emphasized that the generation of MSW varies according to various factors, including economic, social and political level, and that these characteristics, together with the results obtained on the basis of preferences and consumption trends, represent valuable information [13]. Since from this information it is possible to estimate or predict possible changes in consumption trends and the incidence of MSW generation, from the present study it is believed that one of the main characteristics is the socioeconomic level [10]. There is evidence that the trend in waste generation varies according to purchasing power, due to the activities carried out within the home, as well as customs in relation to geographic location [10]. Also, in Latin American and Caribbean countries with similar socioeconomic conditions, the waste generated is mostly composed of food waste with energy recovery capacity [1], [28].

On the other hand, the aspects analyzed in this document aim to explain the MSW generation based on the characteristics of the community. These characteristics involve not only the demographic composition, but also the relational aspect between consumption patterns and the type of waste generated. Thus, each population settlement (i.e., urban and rural) will have different characteristics due to the different needs that arise. It is evident that urban population growth has been increasing in the last five years, which translates into an increase in the MSW generation. In addition, household aspects also differ according to geographic location. In urban and rural environments, the use of fuels or electrical resources varies according to the activity, which means that their characterization varies too.

Therefore, if the aim is to incorporate or improve MSW management policies, it is necessary to consider the criteria mentioned above in order to obtain functional results.

However, it is known that such integration with the objective of achieving sustainable development represents an important challenge, particularly in developing countries with a constantly increasing population, so that knowing and identifying the limitations is an important part to consider in future research.

4 FUTURE RESEARCH PROJECTIONS

For an efficient integration of measures that contribute to the mitigation of the damage caused by MSW generation, it is necessary to know what causes it; in this case, the relationship between consumption patterns and solid waste generation was analyzed. As it is known in Peru, not all municipalities have an integrated management system for the benefit of local development. In this sense, it is convenient to include in the current regulations all phases of generation, that is, not only the collection, transfer and final disposal, but also the identification of consumption patterns and their impact on MSW generation. In this way, it is possible to contribute to the implementation of more appropriate tools if characteristics such as geographic location, socioeconomic status, customs, preferences, among others, are considered, since these characteristics can explain in a more appropriate way the differentiation of MSW generation rates. For better data quality, it is also recommended to conduct interviews with more specific questions that contribute directly to the analysis of consumption patterns, since their role in the generation of solid waste is evident. In relation to the integration of policies involving MSW management between the public and private sectors, it is also necessary to include sustainable financing structures. Finally, it is intended that based on this analysis, future research will be initiated to work directly with the cause and not only with the consequences of MSW generation, in order to obtain sustainable results that contribute not only to the mitigation of the damage already generated at the environmental, social and economic level, since it is our responsibility to modify the production and consumption model to help create sustainable development and a better future for all.

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REFERENCES

[1] Hernández-Berriel, M. del C. et al., Generation and composition of municipal solid waste in Latin America and the Caribbean. *Rev. Int. Contam. Ambient*, **32**(1), pp. 11–22, 2016.

[2] Liu, J., Li, Q., Gu, W. & Wang, C., The impact of consumption patterns on the generation of municipal solid waste in China: Evidences from provincial data. *Int. J. Environ. Res. Public Health*, **16**(10), pp. 1–19, 2019.

[3] Hoornweg, D. & Bhada-Tata, P., What a waste: A global review of solid waste management. Urban Development Series, Knowledge Papers no. 15. World Bank: Washington, DC, 2012. https://openknowledge.worldbank.org/handle/10986/17388.

[4] Cárdenas-Mamani, Ú., Kahhat, R. & Vázquez-Rowe, I., District-level analysis for household-related energy consumption and greenhouse gas emissions: A case study in Lima, Peru. *Sustain. Cities Soc*., 103572, 2022.

[5] Tassie Wegedie, K., Households solid waste generation and management behavior in case of Bahir Dar City, Amhara National Regional State, Ethiopia. *Cogent Environ. Sci*., **4**(1), 2018. DOI: 10.1080/23311843.2018.1471025.
[6] Sedighi, A., Karrabi, M., Shahnavaz, B. & Mostafavinezhad, M., Bioenergy production from the organic fraction of municipal solid waste and sewage sludge using mesophilic anaerobic co-digestion: An experimental and kinetic modeling study. *Renew. Sustain. Energy Rev*., **153**, 2022.
[7] Mesjasz-Lech, A., Municipal urban waste management: Challenges for Polish cities in an era of circular resource management. *Resources*, **10**(6), p. 55, 2021. https://www.mdpi.com/2079-9276/10/6/55. Accessed on 23 May 2022.
[8] Huamaní Montesinos, C., Tudela Mamani, J.W. & Huamaní Peralta, A., Solid waste management of the city of Juliaca, Puno, Perú. *J. High Andean Res*., **22**(1), pp. 106–115, 2020.
[9] INEI, National Household Survey (ENAHO), 2018. http://iinei.inei.gob.pe/microdatos/. Accessed on: 23 May 2022.
[10] Secretaría de Medio Ambiente y Recursos Naturales, Mexico's State of the Environment Report 2018, 2019.
[11] Rada, E.C. & Cioca, L., Optimizing the methodology of characterization of municipal solid waste in EU under a circular economy perspective. *Energy Procedia*, **119**(July), pp. 72–85, 2017.
[12] Sharma, B.K. & Chandel, M.K., Life cycle cost analysis of municipal solid waste management scenarios for Mumbai, India. *Waste Manag*., **124**, pp. 293–302, 2021.
[13] Guerrero, L.A., Maas, G. & Hogland, W., Solid waste management challenges for cities in developing countries. *Waste Manag*., **33**(1), pp. 220–232, 2013.
[14] Khatib, I., Municipal solid waste management in developing countries: Future challenges and possible opportunities. *J. Green Eng*., **10**(10), pp. 8788–8797, 2011.
[15] INEI, Peru: Sociodemographic profile, 2018. https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1539/cap06.pdf.
[16] INEI, Database. http://iinei.inei.gob.pe/microdatos/.
[17] SINIA, Environmental statistics, 2020. https://sinia.minam.gob.pe/informacion/tematicas?tematica=08.
[18] Municipalidad Metropolitana de Lima, Integral Plan for the Environmental Management of Solid Waste in the Province of Lima 2015–2025, Perú, 2014.
[19] Aragón Cruz, A. & Córdova, A., Separation of recyclable inorganic waste in Tijuana. *Rev. Int. Contam. Ambient*., **35**(4), pp. 1011–1023, 2019.
[20] Zaman, A.U., Identification of key assessment indicators of the zero waste management systems. *Ecol. Indic*., **36**, pp. 682–693, 2014. https://linkinghub.elsevier.com/retrieve/pii/S1470160X13003567.
[21] ONU Medio Ambiente, Perspective of waste management in Latin America and the Caribbean, 2018. https://www.unenvironment.org/es/resources/informe/perspectiva-de-la-gestion-de-residuos-en-america-latina-y-el-caribe.
[22] OSINERGMIN, Electricity Consumption and Uses Results Report Residential Energy Consumption and Uses Survey, ERCUE 2019–2020, 2021.
[23] OSINERGMIN, Results Report on Consumption and Uses of Liquid Hydrocarbons and LPG Residential Energy Consumption and Uses Survey, ERCUE 2019–2020, 2021.
[24] INEI, National Household Survey (ENAHO), 2020. http://iinei.inei.gob.pe/microdatos/.

[25] INEI, Socioeconomic characteristics of the agricultural producer in Peru. IV National Agricultural Census 2012. *Inst. Nac. Estad. e Inform*., **388**, 2014. https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1177/libro.pdf.
[26] Muisa Zikali, N., Chingoto, R.M., Utete, B. & Kunedzimwe, F., Household solid waste handling practices and recycling value for integrated solid waste management in a developing city in Zimbabwe. *Sci. African*., **16**, e01150, 2022. DOI: 10.1016/j.sciaf.2022.e01150.
[27] OSINERGMIN, Results Report on Consumption and Uses of Liquid Hydrocarbons and LPG Residential Energy Consumption and Uses Survey, ERCUE 2018, 2020. http://www.osinergmin.gob.pe/newweb/pages/Estudios_Economicos/77.htm.
[28] Aguilar-Virgen, Q., Taboada-González, P., Ojeda-Benítez, S. & Cruz-Sotelo, S., Power generation with biogas from municipal solid waste: Prediction of gas generation with in situ parameters. *Renew. Sustain. Energy Rev*., **30**, pp. 412–419, 2014.

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ANALYSIS OF WASTE VOLUME AND TYPE GENERATED IN O.R. TAMBO DISTRICT MUNICIPALITY, SOUTH AFRICA

NELISA TEMBANI, MOTEBANG D. V. NAKIN, ZENDY MAGAYIYANA & ASABONGO MNGENI
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ABSTRACT

The volume and varieties of municipal solid waste have increased rapidly because of economic growth, urbanization, and industrialization. The foundations for proper solid waste management planning are quantification and classification of municipal solid waste, but the requirements for collection, transportation, classification, and disposal are grossly under-invested and hardly implemented. As a result, the focus of this research is on the amount and types of waste generated in the O.R. Tambo district municipality. The O.R. Tambo district municipality has implemented a regional recycling program as part of an integrated solid waste management strategy to ensure waste management in its five local municipalities is sustainable. In a 31-month period, the total amount of waste material processed in the five local municipalities was projected to be 2,171.63 tonnes. The types of waste collected in O.R. Tambo district municipality include cardboard (K4), plastic (PET, HDPE, LDPE, and LLEPD), aluminium, and white paper. The study used two-way analysis of variance to compare the means of different waste types that are collected in the study area. The five local municipalities have varying quantities and compositions of waste. The findings of the study demonstrate that different local municipalities were selective in terms of the waste they recycled, which motivated waste pickers to gather certain waste streams from the streets and dump sites. Solid waste generation reduction, proper training, and the implementation of incentive and other fiscal policies were identified as hurdles to effective solid waste management, and recommendations for integrated solid waste management strategies were presented.

Keywords: integrated solid waste management, buy-back centres, recycling, informal sector, street waste picker, job creation.

1 INTRODUCTION

Waste management is a global issue, which confronts several countries due to the rising human population, production, and consumption of waste levels [1]. Poor waste management techniques can harm the environment and impede a country's ability to achieve long-term growth [1]. Waste is a hazard to both human health and the environment, which is why many governments are grappling with it and are developing procedures, policies, and laws to regulate waste management. For example, the United Nations has expressed concerns about environmental protection and the need to adopt policies that support sustainable development [2].

Waste management in South Africa has previously been haphazard and underfunded [3]. Poor waste management include, unlawful dumping, unlicensed waste management facilities, overuse of landfills, insufficient waste minimization and recycling initiatives. Furthermore, a high percentage of human population's lack of information relating to waste management and legislation enforcement, thus waste management remains a major concern. As a result, the South African government has dedicated itself to ensuring environmental preservation through the implementation of many legislations such as the National Environmental Management Waste Act 2008 (Act No. 59 of 2008), Municipal Systems Act (Act No. 32 of 2000) amongst others ensuring that waste management concerns are given the attention they deserve.

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In terms of the regulations and roles allocated to local government, one of the responsibilities of local municipalities is to deal with refuse removal, refuse dumping, and solid waste disposal (Constitution of the Republic of South Africa, 1996) [4]. Each municipality is responsible for developing municipal by-laws that address waste management explicitly, and these by-laws are directed by the National Legal Framework Scholars, such as Fathi et al. [5] who opine that municipalities should emphasize a waste management hierarchy that begins with waste prevention, waste reduction, resource recovery, waste treatment, and the last resort being waste disposal. Municipalities in the performance of their powers and functions related to refuse removal, refuse dumps, and solid waste disposal demands for integrated waste management strategies [6], [7].

Out of the five mentioned waste management strategies, waste minimization is one of the most popular solutions because it entails modifying behaviours and supporting the adoption of the three R's of waste minimization: Reduce, Reuse, and Recycle [8]. In this context the term "recycling" refers to the reprocessing of discarded waste materials for reuse, which includes gathering, sorting, processing, and transforming waste materials into raw materials that can be utilized to make new materials [9]. Furthermore, recycling activities have increased in most countries throughout the world because of their both environmental and economic benefits such as extending the life of raw materials and maximizing the value recovered from them; recycling also lessens the demand for them. It lessens the environmental damage, pollution, and waste that come with the extraction of new materials. Each tonne of recycled glass, for example, prevents around 315 kg of carbon dioxide from entering the atmosphere because of refining procedures. It lowers the costs and emissions associated with moving raw materials and creating new goods. Recycling also helps in combating climate change, whilst on the other hand recycling saves money on waste disposal. When compared to the energy used to produce raw materials, it saves energy during the manufacturing process. Recycling paper, for example, uses 28–70% less energy than producing new paper [10]. It provides job opportunities while also reducing raw material imports [11]–[14]. Recycling involves isolating reusable products from the remainder of the waste stream, and returns commodities to the market. As such, Muzenda [3] claims that recycling is the most visible and achievable waste management method.

2 THE ROLE OF BUY-BACK CENTERS IN THE RECYCLING INDUSTRY

Papers, cardboards, plastic material, and scrap metals are the most often collected recyclables that are sold to buy-back centres (BBCs) [10], [14]. The value of recyclables is determined by the forces of supply and demand in that commodity market. As a result of this circumstance, some recyclables are more valuable in one location than in another. For example, literature has shown that in South Africa the biggest demand for paper and plastic material is in Johannesburg, whereas cardboards are in demand in Durban [15].

According to Viljoen et al. [16] BBCs are also picky about the recyclables they buy from waste collectors. Paper in all forms is the recyclable product purchased by most BBCs; white paper is the most purchased by 82.1%, followed by newspaper (79%), while the magazines and books are sitting at 70.1%, mixed paper 70.1%, and cardboard 71.6% to BBCs. When looking at other recyclables, cans are most purchased (56.7%) by BBCs, followed by glass (46.3%), globes (26.9%), and bottles (32.8%) [16]. BBCs compete for certain recyclables to offer recycling firms with sustainable amounts [16]. If BBCs are close enough to each other, some waste collectors sell all their recyclables to one BBC, while others sell each recyclable to the BBC that provides the highest price because there is great demand for the recyclables. This indicates that the BBCs are competing to attract larger and more sustainable volumes of recyclables. Furthermore, some BBCs, particularly those in locations where there are no other

BBCs nearby, find it difficult to maintain their commitment by purchasing all recyclables from waste pickers, even though some recyclable products may not be profitable to BBCs.

The regional recycling project was initiated and is currently being implemented by the O.R. Tambo district municipality as part of the implementation of its Integrated Waste Management Plan. The establishment of the regional recycling project aimed at linking the informal sector waste management and recycling companies, thereby creating both formal and informal employment in the recycling chain. The regional recycling project helps to minimize unemployment, promote recycling efforts and cooperatives within the region, reduce waste sent to landfills, and boost local economic development.

In all five local municipalities in the O.R. Tambo district municipality there are recycling BBCs. According to Hettiarachchi et al. [17] waste collection via BBCs is crucial for involving the informal sector in the recycling business. BBCs are for-profit businesses where anyone can sell recyclable waste. Types of recyclable waste include paper, cardboard, plastics, aluminium cans, and glass [18]–[20]. Due to limited data, it is difficult to determine the number and the extent of BBCs in South Africa.

BBCs in South Africa rely significantly on the waste collected by waste pickers from the informal sector. BBCs are typically positioned near an industrial and/or commercial hub, making them more accessible to informal waste collectors who lack access to long-distance transportation [20]. Waste pickers are encouraged to deliver the material clean and classify it into various categories to obtain the greatest potential payment. The BBCs sell the recyclables they gather to large recycling firms, making them "middlemen" who serve an essential role as a link between the official and informal sectors [17].

The goal of this study was to determine if there are differences in the amount as well as the type of waste produced in the five local municipalities in the O.R. Tambo district municipality. We hypothesize that the volume and type of waste generation across the five local municipalities of the O.R. Tambo district municipality is the same.

3 MATERIALS AND METHODS

3.1 Study area and site location

The research was carried out in the five local municipalities (Ngquza Hill, Port St Johns, Nyandeni, King Sabata Dalindyebo, and Mhlontlo) of the O.R. Tambo district municipality in the Eastern Cape Province of South Africa (Fig. 1). The overall area of the O.R. Tambo district is approximately 12,095.1 km^2 [21]. The district is designated as a Category C2 Municipality, which denotes a predominantly rural area. At least 80% of the district was once part of the Transkei, and nearly a third of the population lives in scattered homesteads and tiny communities. Except for King Sabata Dalindyebo Local Municipality (KSDLM), all local municipalities in the district are categorised as Category B4 Municipalities, indicating a rural but primarily subsistence economy [21]. The KSDLM is a Category B2 Municipality, which indicates it has a large core town with significant market and business activities and prospects, as well as a relatively fertile agricultural area.

3.2 Sampling

Information about waste volume and different waste types collected in BBCs across the different local municipalities of O.R. Tambo district municipality were solicited using purposive sampling from the O.R. Tambo District Environmental Management Unit.

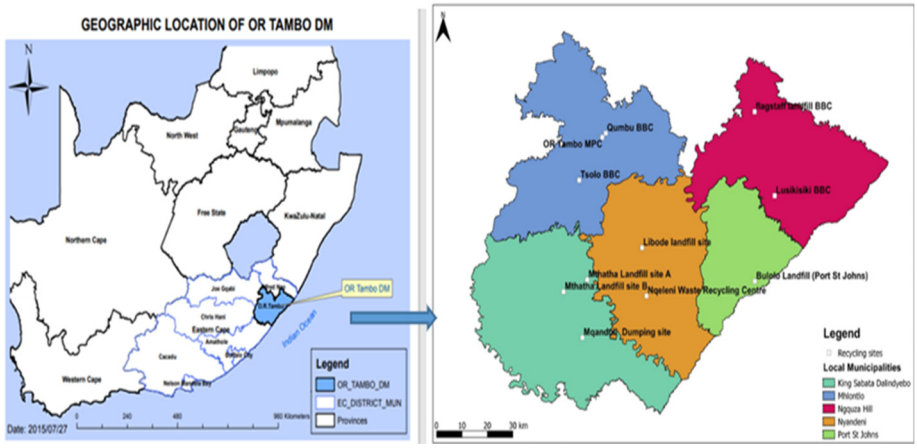

Figure 1: Geographic location of O.R. Tambo district municipality and its BBCs.

3.3 Data analyses

Data entry screens were established in Statistical Package for Social Sciences. We compared the amount and type of waste collected in the BBCs across the five local municipalities using data that were collected over a 31-month period. Using the Statistical Package for Social Sciences (SPSS Version 25), the data was statistically examined. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to determine whether the data was normally distributed or not. Both tests revealed that the data set was not normally distributed ($p < 0.05$), necessitating the use of a non-parametric test (two-way analysis of variance (ANOVA)). A non-parametric statistic known as the two-way ANOVA was used to compare the mean values of amount and type of waste recycled in O.R. Tambo district municipality. The two-way ANOVA is a substitute to the one-way ANOVA. It is used to see if the means of compared variables have any significant differences. P-values > 0, 05 were considered not to be statistically significant different.

Our analysis employed a two-way ANOVA followed by Tukey's multiple comparison test. ANOVA was used to examine the different types of waste material recycled across the various local municipalities in the O.R. Tambo district municipality and determine which recyclable was more recycled. A value of $p < 0.05$ was considered statistically significant.

4 RESULTS

A total of 2,171.63 tonnes of waste were processed from BBCs. The amount of waste recycled was significantly different for all fixed or independent variables: local municipality ($F = 7.37$, $P < 0.001$), type of waste ($F = 26.94$; $P < 0.001$) and interaction between these factors ($F = 3.63$; $P < 0.001$) as indicated in Table 1. The study findings show that Mhlontlo local municipality had significantly the highest amount of waste compared to other four local municipalities (Table 2 and Fig. 2). However, the amount of recycled waste at KSDLM did not differ from the amount recycled at Nyandeni, Port St Johns local municipality and Ingquza local municipality (Table 2 and Fig. 2). Similarly, the amount of waste recycled at Nyandeni local municipality is like that at Port St Johns and Ingquza Hill local municipality (Table 2 and Fig. 2). Port St Johns and Ingquza Hill local municipality had the same amount of waste recycled (Table 2 and Fig. 2).

Table 1: Tests of between-subjects' effects.

Tests of between-subjects effects					
Dependent variable: Total volume generated					
Source	**Type III sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Corrected model	6391773343897.383[a]	19	336409123363.020	8.177	.000
Intercept	2064022696628.495	1	2064022696628.495	50.168	.000
Type of waste	3324949041884.979	3	1108316347294.993	26.939	.000
Local municipality	1213324951050.458	4	303331237762.615	7.373	.000
Type of waste × Local municipality	1792154904725.186	12	149346242060.432	3.630	.000
Error	24602959829936.953	598	41142073294.209		
Total	33074577309523.816	618			
Corrected total	30994733173834.336	617			

[a] R squared = .206 (adjusted R squared = .181).

Table 2: Two-way ANOVA multiple comparison test of the different volumes of waste collected for recycling in the five local municipalities of the O.R. Tambo district.

(J) Name of the local municipality	**Mean difference (I–J)**	**Std. error**	**Sig.**	**95% Confidence interval**	
				Lower bound	**Upper bound**
Mhlontlo; KSDLM	107788.64*	25760.082	.000	37305.99	178271.30
Mhlontlo; Nyandeni	134099.79*	25760.082	.000	63617.14	204582.44
Mhlontlo; Port St Johns	81175.87*	25812.387	.015	10550.10	151801.63
Mhlontlo; Ingquzahill	77893.57*	25812.387	.022	7267.81	148519.34
KSDLM; Nyandeni	26311.15	25760.082	.846	−44171.51	96793.80
KSDLM; Port St Johns	−26612.78	25812.387	.841	−97238.54	44012.99
KSDLM; Ingquzahill	−29895.07	25812.387	.775	−100520.83	40730.69
Nyandeni; Port St Johns	−52923.92	25812.387	.243	−123549.69	17701.84
Nyandeni; Ingquzahill	−56206.22	25812.387	.190	−126831.98	14419.55
Port St Johns; Ingquzahill	−3282.29	25864.586	1.000	−74050.88	67486.29

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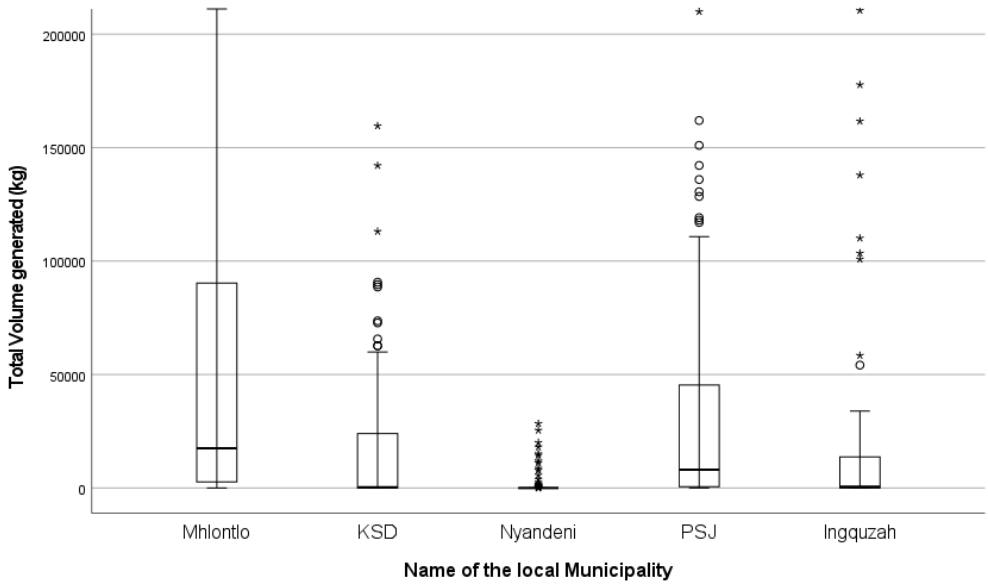

Figure 2: Total volume of waste recycled by location.

In terms of waste recycled by type, the study findings show that cardboard was the most recycled type of waste unlike the other three types of waste (Table 3 and Fig. 3). However, other types of waste (plastic, aluminium, and white paper) did not differ in terms of the amount of waste recycled.

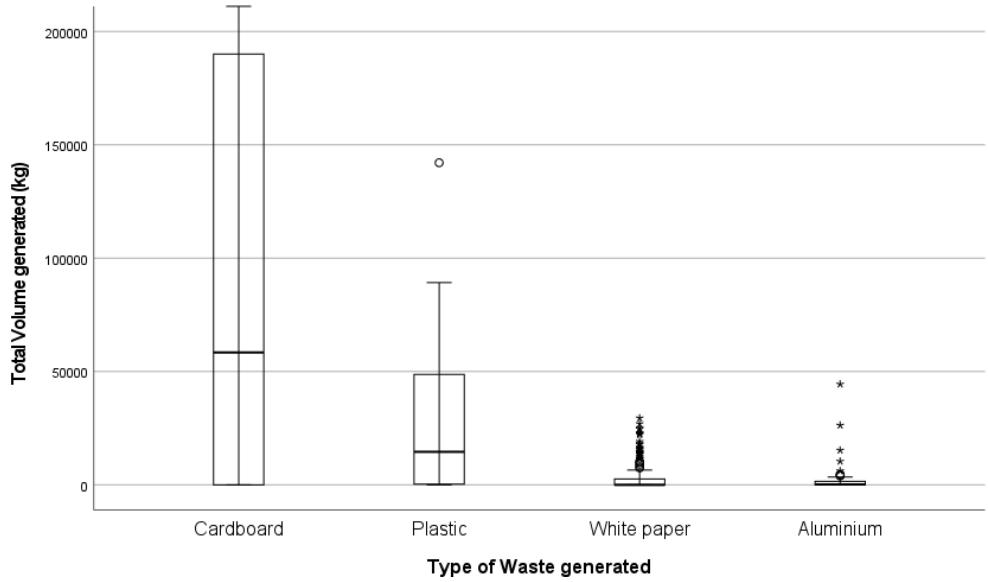

Figure 3: Total volume by type of waste in O.R. Tambo.

Table 3: Two-way ANOVA multiple comparison test of the different types of waste volumes collected for recycling in the five local municipalities of the O.R. Tambo district.

(J) Type of waste generated	Mean difference (I–J)	Std. error	Sig.	95% Confidence interval	
				Lower bound	Upper bound
Cardboard; Plastic	137899.02*	23077.891	.000	78444.16	197353.88
Cardboard; White paper	178436.33*	23040.518	.000	119077.76	237794.91
Cardboard; Aluminium	180716.45*	23077.891	.000	121261.59	240171.31
Plastic; White paper	40537.32	23077.891	.296	−18917.55	99992.18
Plastic; Aluminium	42817.43	23115.204	.250	−16733.56	102368.42
White paper; Aluminium	2280.11	23077.891	1.000	−57174.75	61734.97

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5 DISCUSSION

5.1 Collection by type of waste

5.1.1 Cardboard (K4)

Cardboard was compared across all local municipalities, and the results revealed that the amount of cardboard collected by the local municipalities differed statistically significantly. This is evident in Fig. 3. These findings match those of research done by Schenck and Blaauw [14]. However, these results are contrary to those of Viljoen et al. [20] who discovered that white paper is the most recyclable waste product in Pretoria, whereas the price of white paper is substantially lower in Bloemfontein. This could be attributed to higher transportation expenses because of the BBC's greater distance from recycling companies. Furthermore, PET is sold at the highest price per kilogram in Bloemfontein.

5.1.2 Plastic

According to Viljoen et al. [16], BBCs are discriminating in the recyclables they purchase from waste collectors. There was a statistically significant difference in plastics (PET, HDPE, LDPE, and LLEPD) between the five local municipalities. For example, plastic consumption was higher in three local municipalities: Mhlontlo, King Sabatha Dalindyebo, and Port St Johns. In contrast to what was happening in the Johannesburg metropolitan region, where white paper was in strong demand, steel cans were the most popular [15]. The value of recyclables is defined by the forces of supply and demand in that commodity market, according to Viljoen et al. [16]. As a result, some recyclables are more valuable in different places, resulting in discrepancies in the types of recyclables collected by BBCs.

Pricing discrepancies in recyclable items, according to Schenck and Blaauw [14] incentivize waste pickers all over the world to be selective and collect only waste for which there is a market, therefore supplying the BBCs with higher-value recyclables. Plastics are sold to BBCs in four main types. The findings revealed that waste collectors in Mhlontlo and the KSDLM sold PET (polyethylene terephthalate) at buy-back facilities, and that plastic, particularly PET, is very valuable on the market and produces extra jobs.

According to Hayami et al. [22] one of the reasons why not all BBCs buy PET is that they do not have enough space to store large quantities of PET, especially if there is no bailer, and there are high costs associated with transporting PET over long distances, especially if the recycling companies to whom the BBCs sell are far away, and selling small volumes of plastics makes recycling uneconomical and non-beneficial [16]. Because the O.R. Tambo district's main processing centre, which connects informal recycling to recycling companies, is in Mhlontlo local municipality in this case, more PET was collected in BBCs near the main processing centre due to the ease with which their waste could be transported in large volumes.

5.1.3 White paper

When the white paper's findings are evaluated across all municipalities, statistically significant differences emerge. Mhlontlo and Port St Johns local municipalities collect more white paper. This is most likely since these municipalities have no rivals (private BBCs). The Municipality and Schools in the Municipalities, as well as other government departments such as the South African Police Services, were some of the paper's sources. Because it is the economic core of the O.R. Tambo district municipality and has numerous schools and government departments that use white paper, it is projected that KSDLM BBCs will have

the biggest volumes of white paper collected. Because waste collectors in the local KSDLM operate several buy-back facilities that are not part of the regional recycling program, this is the reason.

5.1.4 Aluminium

The amount of aluminium collected in the five local municipalities differ statistically significantly. However, it is worth nothing that many waste collectors claim that they do not collect aluminium because huge quantities are required to realize the worth of the waste products. Because of space constraints and the fact that the material must be processed before being sold to recycling firms, not all buy-back facilities were able to purchase aluminium from waste collectors. Additionally, there are numerous private aluminium collectors throughout the O.R. Tambo district who collect the material and sell it straight in Durban, thus aluminium has the least recorded waste type in the Municipality records.

5.2 Collection by location

The study findings show that Mhlontlo local municipalities collected more waste than other municipalities followed by Port St Johns local municipality, followed by KSDLM, followed by Ingquza Hill local municipality and then Nyandeni local municipality as the least waste collector in the district as shown in Fig. 2. This is likely because Mhlontlo local municipality has three BBCs, all of which are operational, and there are no competitors in the area. This local municipality also houses the major processing centre, making it easier for collectors to carry their collections to the processing plant.

6 CONCLUSION

The goal of this study was to evaluate the various waste types and volumes collected by the municipality of O.R. Tambo district. The various waste types that are mostly collected in the research locations as well as the overall amount of waste collected by each local municipality are the specific topics that have been examined in this study. According to the study's findings, there are statistically significant differences between the various waste types that were collected in the study area. The volume of waste collected throughout the five local municipalities of O.R. Tambo district municipality also showed statistically significant differences.

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REFERENCES

[1] Mazzanti, M. & Zoboli, R., Waste generation, waste disposal and policy effectiveness: Evidence on decoupling from the European Union. *Resources, Conservation and Recycling*, **52**(10), pp. 1221–1234, 2008.

[2] Davids, I., Theron, F. & Maphunye, K.J., *Participatory Development in South Africa: A Development Management Perspective*, Pretoria Van Schaik Publishers, 2005.

[3] Muzenda, E., Recycling situation in South Africa: A discussion. *International Journal of Biological, Ecological and Environmental Sciences*, **2**(4), 2013.

[4] Constitution of the Republic of South Africa: Act No 108 of 1996.

[5] Fathi, H., Zangane, A., Fathi, H. & Maradi, H., Municipal solid waste characterization and it is assessment for potential compost production: A case study in Zanjan city, Iran. *American Journal of Agriculture and Forestry*, **2**(2), pp. 39–44, 2014.
[6] Draft National Waste Management Strategy, 2010.
[7] National Waste Management Act: Act No 59 of 2008.
[8] Linzner, R. & Salhofer, S., Municipal solid waste recycling and the significance of informal sector in urban China. *Waste Management and Research*, **32**(9), pp. 896–907, 2014.
[9] Williams, P.T., *Waste Treatment and Disposal*, Wiley, 2005.
[10] Magram, S.F., Worldwide solid waste recycling strategies: A Review. *Indian Journal of Science and Technology*, **4**(6), 2011.
[11] Bagchi, A., *Design of Landfills and Integrated Solid Waste Management,* Wiley: New Jersey, 2004.
[12] Waheed, S.A., Adesola, R.O. & Garba, S.M., Biochemistry of wastes recycling. *International Scientific Journal*, **42**, pp. 169–188, 2022.
[13] Challcharoenwattana, A. & Pharino, C., Co-benefits of household waste recycling for local community's sustainable waste management in Thailand. *Sustainability*, 2015. DOI: 10.3390/SU7067417.
[14] Schenck, R. & Blaauw, P.F., The work and lives of street waste pickers in Pretoria: A case study of recycling in South Africa's urban informal economy. *Urban Forum*, **22**(4), p. 411, 2011.
[15] Maphitha, D., *The Role Played by Substance Waste Pickers in Recycling*, University of Pretoria: Pretoria, 2011.
[16] Viljoen, J., Blaauw, D. & Schenk, C., The opportunities and value-adding activities of buy-back centres in South Africa's recycling industry: A value chain analysis. *Local Economy*, **34**(3), pp. 294–315, 2019.
[17] Hettiarachchi, H., Meegoda, J.N. & Ryu, S., Organic waste buyback as a viable method to enhance sustainable municipal solid waste management in developing countries. *International Journal of Environmental Research and public Health*, **15**, p. 2483, 2018.
[18] Ahsan, A., Alamgir, M., El-Sergany, M.M., Shams, S., Rowshon, M.K. & Nik Daud, N.N., Assessment of municipal solid waste management system in a developing country. *Chinese Journal of Engineering*, 2014.
[19] Gela, E., Municipal solid waste management practices for achieving green architecture concepts in Addis Ababa, Ethiopia. *Technologies*, **9**(48), 2021. DOI: 10.3390/technologies 9030048.
[20] Viljoen, J., Schenck, C. & Blaauw, P., The role and linkages of buy-back centres in the recycling industry: Pretoria and Bloemfontein. *Acta Commercii*, **12**(1), pp. 1–12, 2021.
[21] O.R. Tambo District Municipality: Integrated Development Plan Review, 2019/2020.
[22] Hayami, Y., Dikshit, A. & Mishra, S., Waste pickers and collectors in Delhi: Poverty and environment in an urban informal sector. *The Journal of Development Studies*, **42**, pp. 41–69, 2006.

SECTION 10
CULTURAL HERITAGE SITES

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URBAN MORPHOLOGY AND INDUSTRIAL HERITAGE PERSISTENCE

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ABSTRACT

An important part of the historical Hacienda Nueva changed its land use into a factory and became the first company town in the city of Aguascalientes, Mexico in the year of 1861: San Ignacio. Infrastructures were made to connect the factory to the city, including a stone bridge and roads. Even though the factory is almost lost nowadays, historical facts, foundation walls and infrastructure persist. A parallel situation occurred with the main railway installations in town. During the last two decades, governments have financed restoration works in that place. Most of the manufacturing facilities were recovered by public works. Even though the original buildings changed the use of their architectural space, structures still maintain their industrial designs made in the 19th and 20th centuries. A main goal of this paper is to recognize industrial heritage persistence in the city of Aguascalientes. Changes in the city, besides its increasing urban growth, include several architectural époques; indeed, construction materials. Changes also have occurred in the shape of buildings, windows and entrances. In order to compare historical typologies versus industrial typologies an analysis was done. The biggest three companies in town towards the end of the 19th century used to have leisure activities for workers and owners. But what happened with such architectural unique designs? Can society and governments preserve them? Sustainability politics are necessary to support such places. Government efforts are not enough to preserve industrial heritage, but society can do a lot about it. A survey was made to observe how people perceived urban morphology, heritage persistence and sustainability. Likewise, a qualitative statistical method was applied. Actually, a multifactorial evaluation was done. Furthermore, it is convenient to set new rules to promote a circular economy in order to preserve industrial heritage and make the city a sustainable place to live.

Keywords: urban morphology, industrial heritage persistence, circular economy, sustainability.

1 INTRODUCTION

Architecture and urbanism are always changing the image of the cities, but if we refer to several periods of times, changes and new shapes are evident. Skyscrapers change the skylines and old buildings usually become obsolete. Even though city planning makes a big effort nowadays by controlling zoning and designing new roads, unique buildings tend to disappear, unless city administrators restore them or promote a culture of historic preservation as well as trying to achieve sustainable development goals.

In Aguascalientes City, three main historic industrial facilities can be recognized by historical documents or records, and also by reminiscences of buildings. Aldo Rossi said – based on Poète's theory – that cities tend to remain on their axes of development, maintaining the position of their original layout and growing according to the direction and meaning of their older artifacts, which often appear remote from present-day ones [1, p. 59]. In fact, this becomes monuments persistence. Local history mentions the main Guggenheim American Smelting and Refining Co. (ASARCO), also called GFCM as a big industry, located on the western side of Aguascalientes City [2, p. 225]. According to the census of the city in the year of 1900 the population was 102,416 inhabitants [3]. In the year of 2020, the population of Aguascalientes was 1,425,607 [4]. Also on the western side of the ASARCO facilities there used to be a company town named San Ignacio. A Frenchman, Pierre Cornú, founded this textile factory in the year of 1861. It looks like it intended to become an urban growth pole, but after several years it got isolated from the urban area. It is convenient to mention

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that a main road and a stone bridge were built to communicate both industrial facilities. Further, a third big company built in town was the railroad company. During the years of 1840 to 1850 the first railroad tracks were installed to communicate Veracruz City [2, p. 21] with El Molino, but in fact, this was the beginning of the expansion of an industry that helped a lot with the development of the main cities in Mexico. Porfirio Díaz as a president of Mexico urged to build railroad stations and railway tracks at the ending of the 19th century and at the beginning of the 20th century. But later governments decided to stop promoting the use of trains and some of them became obsolete, as well as train stations and facilities were abandoned throughout the late decades. This is the case of the railway facilities in Aguascalientes. Fortunately, throughout the last two decades, several city administrators have financed restoration works in that place.

So, the three main historical industries mentioned on this paper: ASARCO, San Ignacio company town and the railway station facilities became part of the development of a city that increased its urban growth almost 14 times during 125 years. Nowadays there are left a few traces of the ASARCO company facilities. These include two buildings, the foundation bricks of a big chimney and a large amount of the refuse from melting of metals. This scoria can be seen besides Aguascalientes River nearby.

San Ignacio company town did not last for generations, and a few walls stand still as a persistence of its magnificent past. Contemporary practices of adaptive reuse of buildings – including city planning and society – have forgotten such place for the last decades. In fact, new residential areas nearby create land speculation nowadays.

But the story is different in the case of the railroad installations. Indeed, proximity to the historic centre was essential for the persistence of most of the buildings of such industry. There used to be a special interest by situating railroad stations very close to the centre of the main cities in Mexico. Adaptive reuse of the railroad buildings became a key to preserve them. The main station was restored at the beginning of the 21st century and frequent restoration of the rest of the buildings of the site has happened for the last 22 years.

Urban morphology in Aguascalientes has been conditioned by the persistence of the railroad facilities during the last 100 years. These changes will be explained on the next pages of this article. Also, it can be inferred that the three industrial facilities just mentioned were built to become urban development nodes, but only the railroad services succeeded.

A survey was made to observe how people perceived urban morphology, heritage persistence and sustainability in Aguascalientes. Also, a typological analysis helped demonstrate the historical persistence of buildings and contexts.

2 URBAN GROWTH AND MORHPOLOGICAL APROACH

During the last two decades, urban morphology has been linked with urban growth. Scientists are trying to understand how the city changes in shape and its main causes. Li et al. say: "Urban morphology is an interdisciplinary approach focussing on physical form to reveal the characteristics of transformation and replacement of urban areas over time on various spatial scales" [5, p. 2]. Spatial scales have changed surroundings of cities. Nature has suffered human activity and expansion of cities. So, sustainability seems to be an adequate vision to keep a balance between human activity and natural resources. Sustainable development principles include: social, economic and environmental. Abascal et. al. relate them with the urban form, that facilitates the social, economic, and cultural life of the city, and when a design is inadequate, processes are hindered (e.g. mobility) [6]. This means that the use of sustainability codes can be applied not only as a global concept, but also inside the cities.

Social and cultural aspects include historic centres and those sites that used to be the foundation of a city. Li et al. comment "the urban morphological approach can provide

frameworks to explore and understand the conservation and evolvement of historic cities and towns" [5, p. 3] and also a singular analysis of historical urban development is useful to understand how progress of a society becomes useful or negative for preservation of traditional urban areas.

Nowadays technology used by city planners to analyse urban issues is very advanced. Wang and Debbage comment that applying spatial metrics to quantify urban form offers an opportunity to provide a more holistic view of how urban polycentricity and other aspects of urban form influence congestion within US cities [7]. Indeed, researchers and city administrators can apply spatial metrics to obtain more accurate images of a city. Also, interdisciplinary approaches can help to understand how urban growth affects historic places and environments. The use of cars inside the cities requires dynamics of movement – making time a precious resource. Thus, the faster you get to a place, the better it is. Wang et al. say "urbanization processes are manifested by the change in the physical morphology of cities" [8, p. 1]. Transportation becomes a part of the process of urban changes. So, the fact of going shopping to a place means the use of different transportation means for people, and the urban contexts of a shopping place require spatial and functional adaptations. The practice of being transported has become essential for people. Also, technology used for mass transportation is changing frequently and impacts urban dynamics, for example, during the 20th century; railroad tracks were removed from several historic centres in Mexico in order to give room for improvement of transportation systems.

Correspondingly, Wang et al. say "The development of Earth Observation (EO) technology has significantly lifted our scale of observation above ground to obtain a synoptic view towards cities" [8, p. 3]. Aerial images are useful to analyse urban growth patterns and specially if it affects nature and climate changes. Xiang Zhu et al. consider that in the past decades, satellite remote sensing has been the foundation of data collection and the development of knowledge about our Earth. During that period, new initiatives in global urban mapping have advanced the quality of spatial knowledge [9]. Advantages of such advancements benefit historical analysis of urban growth.

A framework of conservation and evolvement of Aguascalientes historic centre has to do with city planning, sustainability and urban morphology analysis (see Fig. 1). The three industrial heritage facilities mentioned in this paper: San Ignacio company town, ASARCO Company and the railway facilities were situated, as it can be inferred, to become development poles in a city context, but only the railroad station facilities became persistence architecture through the years. The evolvement of the city has to do with such facilities and the historic centre as a significant centrality. The three factories have historic facts that help understand the importance of industry in town. Architecture of these buildings shows fine-looking typologies to be preserved as well as genius loci. The concept of genius loci – introduced by Rossi – refers to a relationship between a place and the architecture built nearby. Rossi says: we consider locus the characteristic principle of urban artifacts; the concepts of locus, architecture, permanences, and history together help us to understand the complexity of urban artifacts. The collective memory participates in the actual transformation of space in the works of the collective, a transformation that is always conditioned by whatever material realities oppose it [1, p. 130]. This indicates there was a sense of the place, including regional construction materials and a landscape interpretation when they were built.

3 METHODOLOGY

A questionnaire was designed to understand people's points of view about architectural persistence, urban morphology and preservation of industrial heritage. It was applied

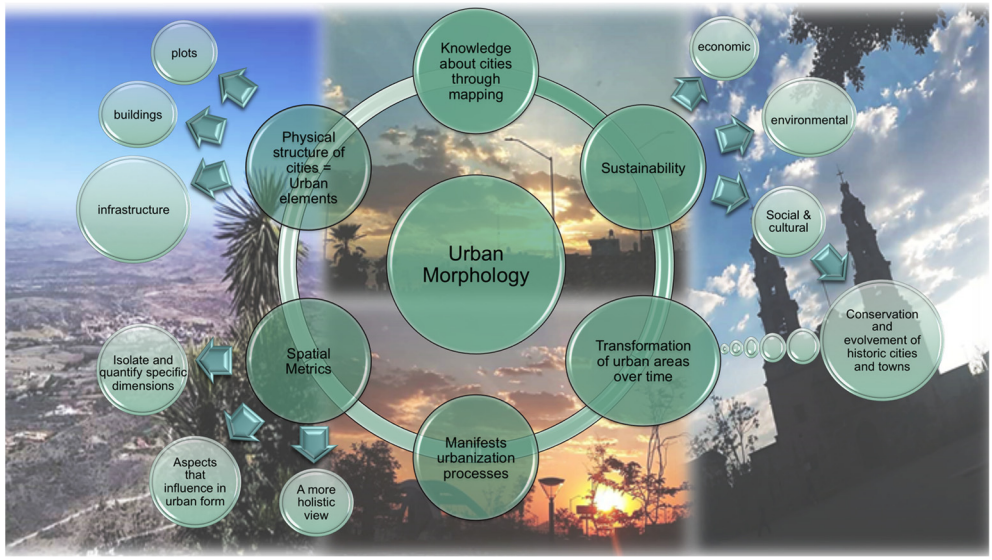

Figure 1: Urban growth and morphological approach. *(Source: Author's research, 2022. Drawing made and edited by Alejandro Acosta Collazo and Judith Areli Segovia Félix. Photographs by Judith Areli Segovia Félix, 9 September 2022.)*

regarding the perception of common people to understand historic persistence of buildings and sustainability aspects. A multifactorial statistical method was used, specifically a multiple correspondence analysis (MCA). The Burt's matrix helped interpret the pattern of interactions of different dependent qualitative variables. The answers were coded as binary variables. The following items were included in the questionnaire: 1. Age of people: Young (13–17), adults (18–60) and senior (+60). 2. Gender: Man or woman. 3. Educational level: Basic studies, undergraduate or post-graduate. 4. Origin: Mexican or foreigner. 5. How do you understand the city growth? It means the size of the city or the shape of the city. 6. How does urban growth affect the historic centre? It affects preservation of historic houses, it makes demolishing of old buildings or it produces urban alteration. 7. Do you consider city planning and urban design important for the city? Yes or no. 8. Why do you think it is important to understand the city limits? So city planners can make a better urban design or to improve mobility or to improve comfort (and life quality of its inhabitants). 9. Do you think excessive tourism could affect the city and heritage buildings? Yes or no. 10. Do you think bad urban planning could affect the city (reason)? This could affect street designs or on architecture typologies or by increasing heavy traffic and pollution. 11. Why do you think it is important to preserve the railroad station and its facilities? Because of its history and preservation of typological facts or for its contribution for city development. 12. What are your memories when you pass by the historic centre? The place means decadence, progress or cultural relevance. See Fig. 2 and the way a Burt's matrix was applied.

Considering that the main goal of the questionnaire was to obtain information about people's point of view concerning historic persistence of buildings and sustainability aspects, question 11 related to importance of history and preservation of typological facts became relevant to connect the questionnaire with a typological comparison. So, a typological

Urban morphology survey

1. Age of people:
☐ Young (13-17) ☐ Adults (18-60)
☐ Senior (+60)

2. Gender:
☐ Man ☐ Woman

3. Educational level:
☐ Basic studies
☐ Undergraduate ☐ Post-graduate

4. Origin:
☐ Mexican ☐ Foreigner

5. How do you understand the city growth?
☐ Size of the city
☐ Shape of the city

6. How does urban growth affect the historic centre?
☐ It affects preservation of historic houses
☐ It makes demolishing of old buildings
☐ It produces urban alteration

7. Do you consider city planning and urban design important for the city?
☐ Yes ☐ No

8. Why do you think it is important to understand the city limits?
☐ So city planners can make a better urban design
☐ To improve mobility
☐ To improve comfort (and life quality of its inhabitants)

9. Do you think excessive tourism could affect the city and heritage buildings?
☐ Yes ☐ No

10. Do you think bad urban planning could affect the city (reason)?
☐ This could affect on street designs
☐ Architecture typologies
☐ By increasing heavy traffic and pollution

11. Why do you think it is important to preserve the railroad station and its facilities?
☐ Because of its history and preservation of typological facts
☐ For its contribution for city development

12. What are your memories when you pass by the historic centre?
☐ The place means decadence ☐ Progress
☐ Cultural relevance

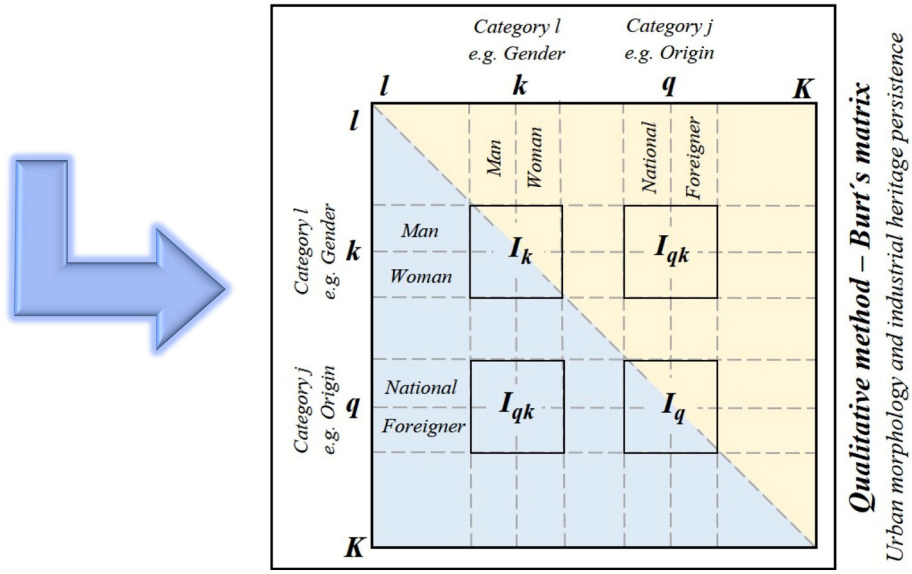

Figure 2: Urban morphology survey and Burt's matrix. *(Source: Author's research, 2022. Drawing made and edited by Alejandro Acosta Collazo and Judith Areli Segovia Félix.)*

comparison was done for this paper, using the shapes of windows of industrial heritage buildings and those mainly used in historic architecture in Aguascalientes historic centre.

4 RESULTS

The statistical information collected from the questionnaire-applied showed that 65% of the inquired people were adults between 18 to 60 years old. 55% of the inquired people have an undergraduate degree. Once the people were asked about understanding of city growth, 70% mentioned the topic had to do with the size of the city, rather than the shape of the city (30%). After asking the people their opinion about seriousness of city planning and urban design for a city a 100% answered: absolutely. Another question was about the importance of understanding city limits and 70% of the inquired people agreed it helped improve comfort and life quality of its inhabitants. An interesting question had to do with tourism and if it had changed city heritage: 60% of the people answered positively. The question about how bad city planning has affected the city was answered as follows: 75% agreed it affected traffic and produced pollution, 15% mentioned architecture typologies were affected and 10% mentioned incorrect street designs.

In relation to the topic of railroad station and its facilities preservation, 60% linked it as a result of historic preservation and 40% as a contribution for city development. And finally, when people were asked about their memories of the historic centre, 85% of the inquired people answered cultural relevance, 10% answered progress and only 5% mentioned decadence.

About the typological contrast, it is convenient to mention that Carranza Street in Aguascalientes keeps the most historic buildings density in town. A scale of blocks was used to compare several historic typologies of entrances and buildings of Carranza Street with Ferronales suburb (see Fig. 3). The reason for choosing Ferronales it was because its persistence architecture throughout the time. Unfortunately, this situation did not happen with the other two companies mentioned at the beginning of this paper: ASARCO Company and San Ignacio company town. The railway facilities, especially Ferronales suburb still keeps industrial heritage typologies in houses. Even though, on Carranza Street long-lasting buildings were basically made of stone and Ferronales buildings were made of wood and metal, sizes of windows – as well as entrances – keep similar shapes. The results of the typological contrast can be seen in Fig. 3. Windows and entrances shapes of typology C (proportion 1:2) can be found also at Ferronales site. This seems to be a casual similitude, but it is not. Construction culture at the beginning of the 20th century was influenced by contextual facts and building traditions brought from abroad e.g. European architectural techniques and in the case of railroad industries from the USA. But apparent contrast of typologies in Carranza Street and Ferronales Suburb becomes a similitude because of the use of shapes of windows and entrances, but not in the way they used construction materials. An exception of this rule is the gothic shapes of typology “F” and “G”, likewise the roman arch of typologies “A” and “H”.

5 DISCUSSION

The Burt’s matrix showed interesting results and also qualitative research interpretations can be stated: 33% of young people (13–17 years old) think urban growth causes alteration on the historic centre. 75% of women inquired said understanding of city limits can help improve comfort and life quality of its inhabitants. 54% of undergraduate people say tourism does not alter the city heritage. This means the more people study the better they understand most of the tourists respect historic places and industrial heritage buildings.

100% of the elderly people (+60 years old) inquired agreed bad city planning increases heavy traffic and pollution. It happens that some city administrators do not correctly analyse

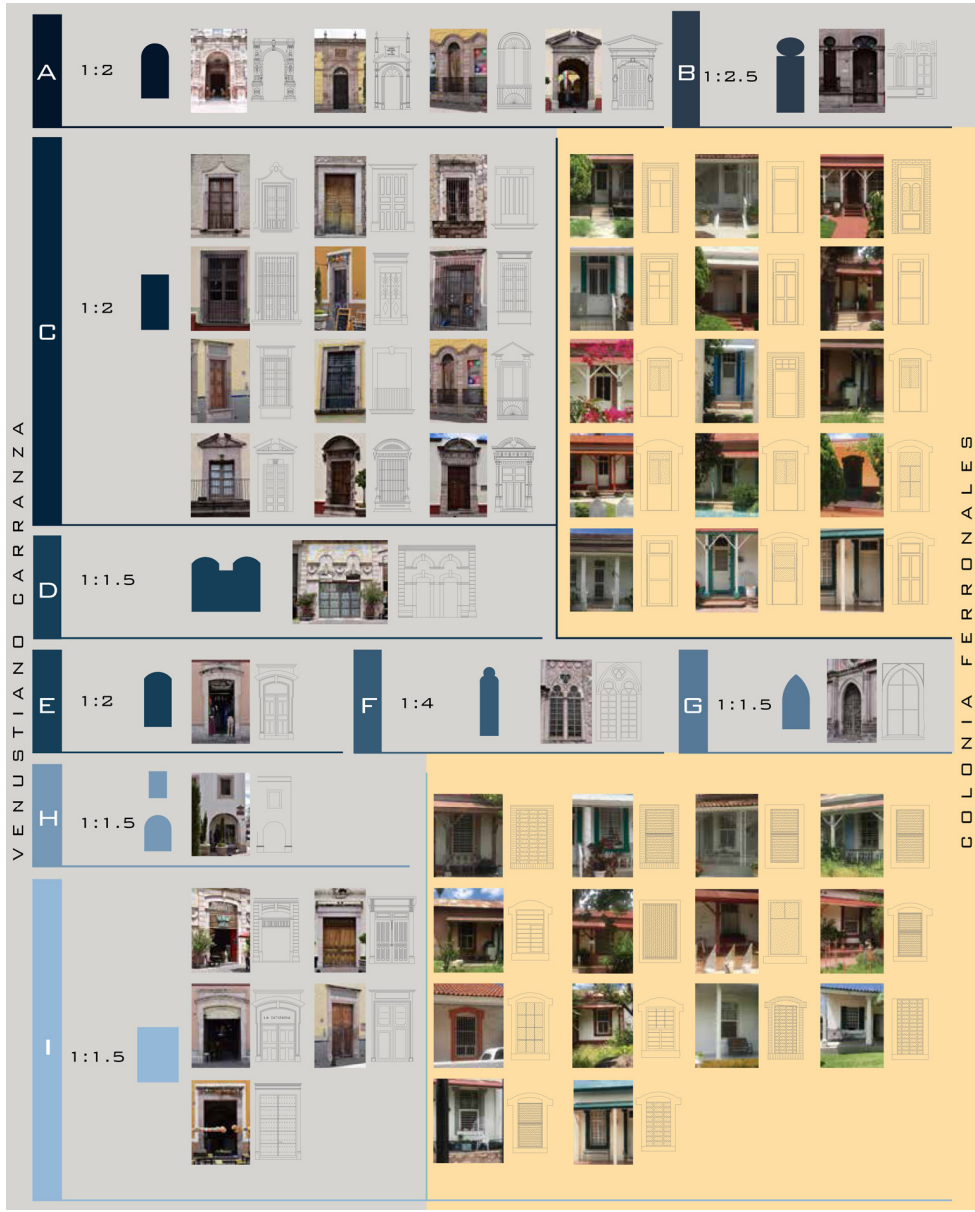

Figure 3: Typological contrast. *(Source: Author's research, 2022. Drawing made and edited by Alejandro Acosta Collazo and María Fernanda Pérez Sifuentes. Photographs by María Fernanda Pérez Sifuentes, 9 September 2022.)*

mobility dynamics and it becomes essential a contemporary point of view on circular economy. Additionally, 50% of inquired women think that preservation of railroad stations and facilities contribute to cultural sustainability. But 75% of inquired men think the same way about this topic.

66% of young people from the survey (13–17 years old) say that historic centres have cultural relevance for society. They also agree heavy traffic and pollution are increasing in the city due to a lack of quality in city planning. This is a common image of the people who were inquired and supported – with valuable answers – to the writing of this paper.

In addition, typological study demonstrates that persistence of iconic buildings have to do with aesthetics, construction materials, contextualization and social recognition. It can be observed in typology "A" (see Fig. 4) the main entrances to buildings keep a proportion of 1:2, but in the "G" entrance (Parroquia El Sagrario); the proportion of the entrance is 1:1.5. Anyway, in the three cases fine woodworking can be observed on the doors and they keep a contextual language with the rest of the street entrances as well. Religious buildings have bigger entrances than houses, but they keep a similar proportion. Most of these important entrances are made with ebony wood.

Figure 4: Comparison of typologies "A" (La Merced and Regional History Museum) with "G" (El Sagrario Church). *(Source: Author's research, 2022. Drawing made and edited by Alejandro Acosta Collazo, Ana Patricia Martínez Alba and María Fernanda Pérez Sifuentes. Photographs by María Fernanda Pérez Sifuentes, 13 September 2022.)*

In order to identify the importance of the historic centre of Aguascalientes – and the city growth – city limits were overlapped, starting from the foundation in 1575 and ending in a nowadays-aerial photograph of the city. Airborne imagery revels glimpse of future and the urgent needs of a circular economy for the city.

Comparing the city limits of 1575 with those of 1855 we can detect that the capital of the state became an example for the rest of the Mexican cities, especially because of the surrounding orchards that helped keep a sustainable place.

It can be observed in Fig. 5 the persistence of the railway facilities for more than 100 hundred years. The shape of the site conditioned somehow the urban morphology of the surrounding suburbs, infrastructure and city limits. This urban development node, besides the historic centre became an important centrality for the whole city. Nowadays there are new centralities, especially those created by the construction of shopping malls.

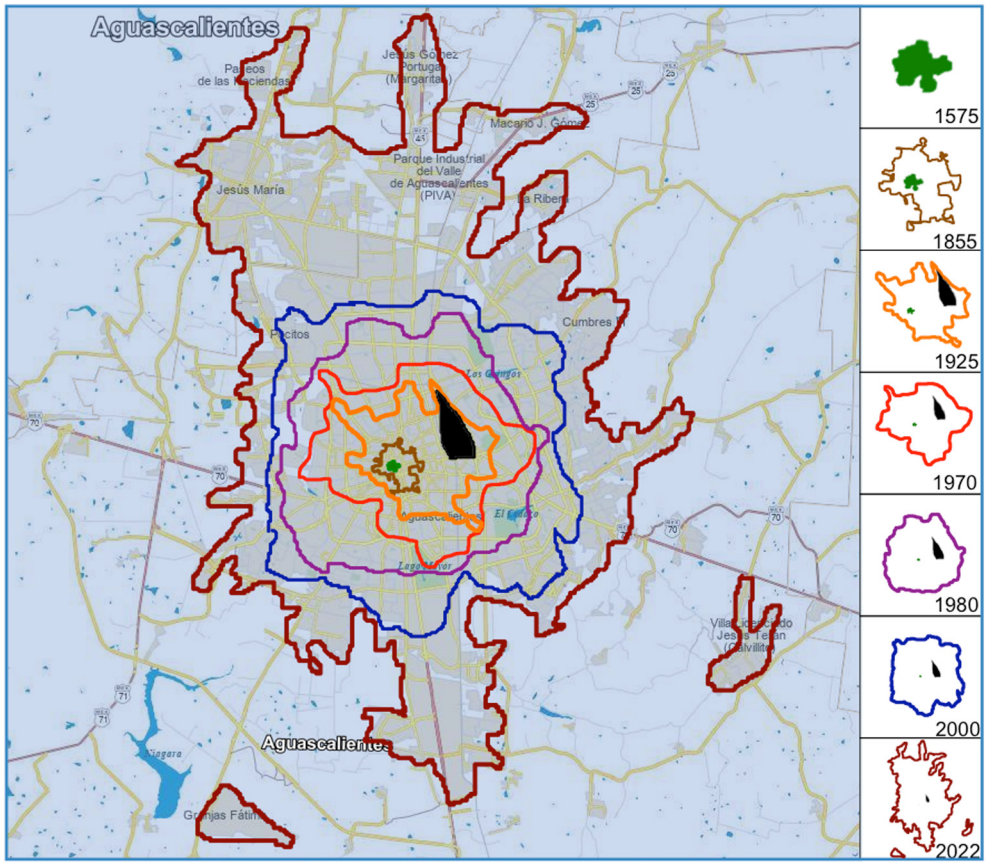

Figure 5: Industrial heritage persistence. Comparison of urban growth and contrast with historic centre, railroad facilities (in black colour) and nowadays morphology. *(Source: Author's research, 2022. Drawing made and edited by Alejandro Acosta Collazo and Judith Areli Segovia Félix. Photograph behind drawing by INEGI 2022.)*

6 CONCLUSIONS

Nowadays researchers can use several methods to study urban morphology. Spatial metrics gives the possibility to quantify detailed areas of a city. Thus, projections can be made on city planning tasks. Also, spatial metrics allows interdisciplinary approaches in order to solve urban issues. But in the evaluation of architecture persistence and sustainable cities, registration of historic phases of urban growth becomes fundamental to understand urban centralities.

The results of the 500 copies of an inquiry form – correctly filled out – were relevant to understand a decay of industrial heritage. Also, the application of a multifactorial statistical method, precisely an MCA – based on a Burt's matrix – was useful to comprehend the pattern of interactions of relevant qualitative variables. Nowadays, persistence of industrial heritage has motivated governments to improve restoration projects in order to preserve what was left of the main railroad station and its facilities. At the present time citizens can observe the

history of a significant industry in the city that conditioned urban morphology throughout the times in Aguascalientes City. But also there are still several challenges ahead: for example, the design of electric trains to attend sustainability measurable aspects of economic, environmental or social systems.

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REFERENCES

[1] Rossi, A., *The Architecture of the City*, The Graham Foundation for Advanced Studies in the Fine Arts, Chicago, Illinois, and The Institute for Architecture and Urban Studies, New York, New York, by The MIT Press Cambridge, Massachusetts, and London, England, 1985.

[2] Gómez, S.J., *Aguascalientes: Imperio de los Guggenheim,* CONAFE/FCE: Mexico, 1982.

[3] INEGI, Estados Unidos Mexicanos. *Cien años de censos de población,* INEGI: Mexico, p. 81, 1996.

[4] Dirección General de Desarrollo Económico, *Principales resultados del Censo Población y Vivienda 2020*, Elaborated by SEDECO, based on Censo de Población y Vivienda 2020, INEGI: Mexico, p. 10, 2020.

[5] Li, J., Dai, T., Yin, S., Zhao, Y., Ikiz Kaya, D. & Yang, L., Promoting conservation or change? The UNESCO label of world heritage (re)shaping urban morphology in the Old Town of Lijiang, China. *Frontiers of Architectural Research*, 2022. DOI: 10.1016/j.foar.2022.05.008.

[6] Abascal, A., Rodríguez-Carreño, I., Vanhuysse, S., Georganos, S., Sliuzas, R., Wolff, E. & Kuffer, M., Identifying degrees of deprivation from space using deep learning and morphological spatial analysis of deprived urban areas. Computers, *Environment and Urban Systems,* **95***,* p. 2, 2022. DOI: 10.1016/j.compenvurbsys.2022.101820.

[7] Wang, M. & Debbage, N., Urban morphology and traffic congestion: Longitudinal evidence from US cities. *Computers, Environment and Urban Systems,* **89***,* p. 2, 2021. DOI: 10.1016/j.compenvurbsys.2021.101676.

[8] Wang, J., Georganos, S., Kuffer, M., Abascal, A. & Vanhuysse, S., On the knowledge gain of urban morphology from space. *Computers, Environment and Urban Systems,* **95***,* 2022. DOI: 10.1016/j.compenvurbsys.2022.101831.

[9] Xiang Zhu, X., Qiu, C., Hu, J., Shi, Y., Wang, Y., Schmitt, M. & Taubenböck, H., The urban morphology on our planet: Global perspectives from space*. Remote Sensing of Environment,* **269**, p. 2, 2021. DOI: 10.1016/j.rse.2021.112794.

TOWARDS A CREATIVE SUSTAINABLE FUTURE FOR HERITAGE DESTINATIONS: A CASE STUDY OF LUXOR, EGYPT

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ABSTRACT
Many countries are beginning initiatives to address the battle between conservation, utilization, and sole reliance on tourism. Heritage destinations are re-profiling to safeguard their sustainability in the market. In this respect, culture is likely to play an increasing role in new sustainable tourism experiences development. The current research aims to explore issues within this context. It studies the development plan for Luxor city, located in southern Egypt, its objectives, and the difficulties that may face this plan implementation. The research also tackles the reopening ceremony of the Avenue of Sphinxes as a case study that was implemented as part of the development plan of the city of Luxor, studying the effectiveness of this development plan as well as the approach of sustainable creativity applied. Thus, qualitative research is used through the focus group technique to collect the needed data from key tourism stakeholders, in which the final sample consists of eight focus groups with five participants in each. Content analysis is conducted and the findings are shown at the end, where four themes are identified. The results highlight future recommendations and development options for the Luxor destination within creative, sustainable boundaries.
Keywords: creative, sustainable, heritage, tourism, development, destination.

1 INTRODUCTION

At a time when distances between the vast world's borders are narrowing in all fields: informational, environmental, cultural, media, and commercial, and many issues and events are dealt with from the perspective of globalization and one village, many countries, regions, and administrative systems still suffer from a gap in coexistence and dealing with the current era's vocabulary. As a result, preparing for and planning for future requirements is essential [1].

The main problem is in translating studies, research, plans, and development goals into an interactive reality among all participating parties. This problem is not caused by a lack of technology, competencies, studies, plans, and research, lack of funding, deliberate bad faith, or unwillingness to realize and reform. Transparency in knowledge and awareness of expected initiatives, as well as consistency in policy execution (independent of who is in charge), which we might call the implementation gap, the lack of clarity of vision, or the administrative system's bureaucracy [2].

The United Nations Development Program's (UNDP) comprehensive development project for Luxor, founded in collaboration with the Ministry of Housing, Utilities, and Urban Communities, is an example of the implementation gap between the aspirations of the international community, government departments, advisory expertise, the investor, and the ordinary citizen in Luxor. In all phases of the project, starting with the stage of reflection and progress to the research stage, then to the funding stage, the implementation stage, the follow-up stage, and finally, the continuity stage. The actual progress of the first stage of the project, which ended with defining the initial vision for the project, was presented at a global international conference on 17 July 1997 [3], where all parties selected were invited to discuss and guide the advisor through the next stages. With the events of Luxor held in


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November 1997, the first phase ended, with the consultant submitting the preliminary concept for the complete development project. Despite the efforts, research, and accomplishments achieved to this point, several issues and obstacles manifested themselves as isolated administrative islands [4].

This research paper aims to look at Luxor's comprehensive development project as an example of multiple international and national bodies, experts, consultants, and citizens working together to create a self-sufficient community based on Luxor while also providing a distinct heritage and tourism product that is commensurate with the international value of Luxor's cultural heritage. The paper discusses the implementation gap that exists in setting the general lines of the vision, despite the effort, because of the marginalization of a major party, Luxor residents, at a time. when the project explicitly states that the vision is dependent on making Luxor city residents the primary beneficiaries of the vision, as well as the fuel and those who work. The research will go through the opening ceremony of the Sphinx Avenue in Luxor, to present a case study on the development plan that was implemented in the city of Luxor, studying the effectiveness of this development plan applying the creative sustainable approach.

2 LITERATURE REVIEW

In contemporary tourism activity, heritage should often be involved as a major tourist product [4]. Heritage tourism attracts more investment to a region with a wide variety of manmade and natural inheritances [5]. The economic significance of heritage resources and cultural destinations has become a vital component in the economic well-being of many destinations. Consequently, sustainable tourism is recognized as promoting the future survival of tourism destinations [4].

In this section, opinions from previous literature and articles will be presented on several points that revolve around the goal of the research. These points included: creative sustainable tourism, Luxor governorate tourism and sustainable renovation, and finally, the opening ceremony of the Sphinx Avenue in Luxor.

2.1 Creative sustainable tourism

Humanity is defined by two characteristics: creativity and sustainability [6]. The principles of creativity and sustainability are used in a variety of fields. These concepts hold different thematic perspectives. When it comes to tourism, creative cultural industries have created items, services, and activities that convey people's ideals, symbols, and ways of life in a particular country [7]. When it comes to the tourism context, sustainability refers to practices and policies aimed at improving and stabilizing the quality of life in a nation [8].

Tourism destinations are seeking to raise new technologies to reduce unsustainable consumption. Many global entities are engaged in green innovation, driven by research and development. Creative tourism helps in developing innovative approaches for sustainable tourism development. In reviewing creative tourism, four aspects have been reoccurring activities: (1) active participation, (2) creative self-expression, (3) learning, and (4) linking to the local community [7]. Creative tourism initiatives seek to construct new ideas and paths, contributing to cultural vitality. It also seeks to serve local collaboration, exchange, and development. Hence, heritage tourism activities have been applied in emerging destinations to develop creative, sustainable modes [8].

The desire of tourists to experience differences through the culture of others is often thought to be a major challenge for host societies in tourist areas. Local communities should have the lion's share in keeping the authentic values of heritage, as they are the owners of

most of the tourism resources within a decision. Tourists, preservationists, and community members all benefit from the community-building strategy. It has been revealed that heritage tourism enhances the socio-cultural and economic benefits of the local community and assists environmental conservation initiatives. That, in turn, boosts sustainable tourism development.

"Cities are hubs of innovation and human ingenuity – and potential centres for transformative action to implement the Sustainable Development Goals and build a zero-carbon, climate-resilient and socially just world". Under the rule of the Egyptian President, the Egyptian community seeks to fast-track the process of balanced sustainable development in the country's governorates to achieve Egypt's 2030 Vision (localization of the country's sustainable development goals). Various initiatives and effective partnerships are set forth to support the efforts to provide a decent life for Egyptians.

2.2 Luxor governorate and sustainable renovation

The governorate of Luxor is situated in Upper Egypt's southernmost section. It includes the cities of Aswan, Qena, Suhag, the Red Sea governorates, and Luxor. Luxor's developments are dated back to the pre-history eras. The city is one of the world's most renowned and magnificent cities. It is the city of one of the earliest civilizations. The city has a long history (dynasties of human history up to the present day), having witnessed the splendour of man's arts and knowledge 7,000 years ago. Luxor has attracted the attention of international organizations concerned with human heritage, including UNESCO. The governorate has been designated as an open museum as part of a comprehensive development strategy.

According to the Luxor Governor, Luxor is witnessing massive developments, exemplifying that the political leadership is paying attention to all governorates as per Egypt's Vision 2030. It adopted a national program for urban development, building new green and smart cities while improving the infrastructure of existing cities. He also mentioned that the Nile Corniche, which stretches for 1.7 km, and the lighting of the West Bank's mountains are among the development initiatives. A new tourist marina will be built in the Karnak Hospital area; the governorate signed a protocol with the Ministry of Housing-affiliated Central Agency for Reconstruction to carry out Luxor's development projects. Luxor is the world's largest open-air archaeological museum.

Luxor is starting to revamp its tourism industry. Several projects are underway as part of the governorates' long-term development strategy. For example, the el-Murayes area, southwest of Luxor, has been selected to establish an international tourist marina, holding 260 floating boat capacity. The Luxor Temple's surrounding area is embracing the construction of the Mosque of Abu Hagag with an open area around the temple and the mosque. The Nubian village is established in the south of Luxor to revive its heritage. Over 1.2 km of streets are being assimilated as old shopping centres in Europe. The Savoy Bazars, a unified mall, is being rebuilt to become the city's largest complex of tourist shops and bazaars. The El-Karnak pavilion is being built, which will clear the temple yard of informal settlements. The reopening of Luxor's Avenue of Sphinxes is occurring, linking Luxor and Karnak temples. These developments are remarkable projects that will go down in history.

The governor is also working to renovate the train station in the city. Roads are also being constructed on the city's outskirts to facilitate entry and exit of tourist buses, thus increasing the number of all means of transportation. Luxor International Airport is being built within the same transportation setting. This airport is to compete with Cairo International Airport in terms of capacity compared.

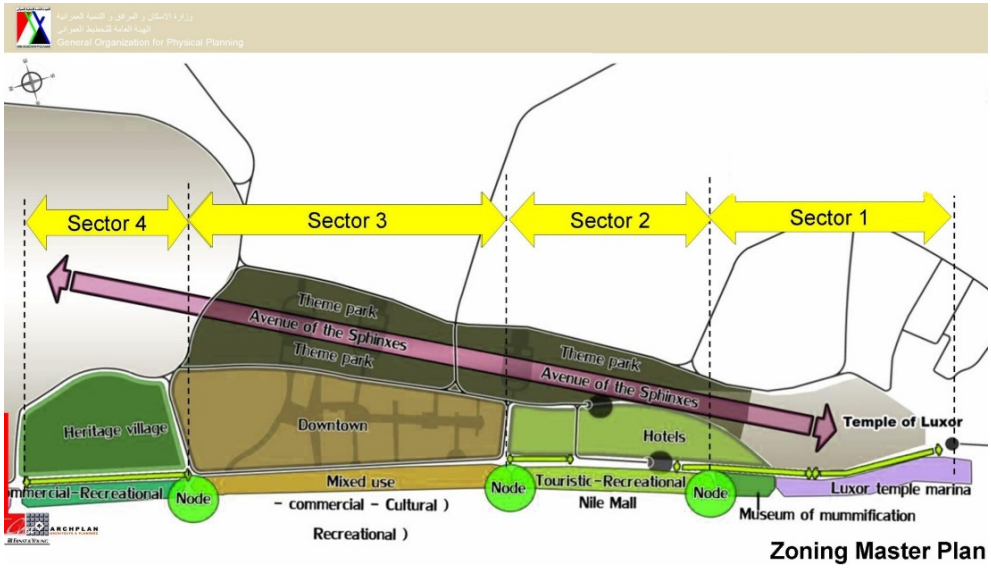

Figure 1: Luxor city zoning master plan. *(Source: General Organization for Physical Planning (GOPP) Egypt. https://cuipcairo.org/en/directory/general-organization-physical-planning-gopp.)*

The Esna Tourism Promotion Campaign was started in Luxor by the US government and the Egyptian Ministry of Tourism and Antiquities as part of the US government's support for the preservation of hundreds of cultural heritage sites around Egypt. Esna, Luxor is home to several tourist attractions, including ancient Egyptian temples and a Coptic Orthodox monastery. This collaboration will promote Esna as a top tourist destination to tour operators, investors, and the public. This project seeks to put Esna back on the tourism map, attracting and allowing global investment opportunities.

These projects are in partnership with the Ministries of Tourism and Antiquities and other various global entities. The projects that are taking place in Luxor Governor are revitalizing cultural tourism. With these developments, the region will see an increase in job creation and increased public and private investment.

Table 1: Sustainable development projects in Luxor.

Development projects
1: Restoration of the Avenue of Sphinxes
2: Development of the destination resort of El-Toad
3: Development of the new community of New Luxor
4: Infrastructure service for New Luxor and El-Toad
5: Establishment of high-value agriculture
6: Creation of an open museum and heritage district in Luxor city

2.3 The opening ceremony of the Sphinx Avenue in Luxor

In November 2021, a legendary celebration of the opening of Sphinx Avenue (Road of the Rams), the oldest historical passage in the world, was launched. The event attracted the whole global market, developing a strong interest in the ancient Egyptian civilization. Guests from all over the world, local and foreign, were in attendance during the event.

About 200 international media correspondents accredited in Egypt attended this huge and legendary party to cover this legendary celebration. The celebration witnessed the screening of a documentary film about the Luxor governorate, entitled "Luxor Secret", displaying the city of Luxor, its most prominent monuments, and tourist attractions. It was presented by a group of artists, members of the Luxor local community, and archaeologists who discussed the religious diversity in Luxor and the various tourist activities in Luxor, such as balloon tours, Nile cruises, local market shopping, and sports and entertainment activities. The film concluded with a message from the Minister of Tourism about Luxor, in which he reassured everyone, saying, "Our country is safe".

The current minister of tourism and antiquities said: "By this legendary celebration, today we not only announce the launch of the Sphinx Venue but also the completion of the German University in Cairo's visual identity work (GUC) and its implementation by the Engineering Authority of the Armed Forces". This is to emphasize how Luxor represents a vibrant tourist destination through tourism activities, sending a message of security and safety to the whole world [9].

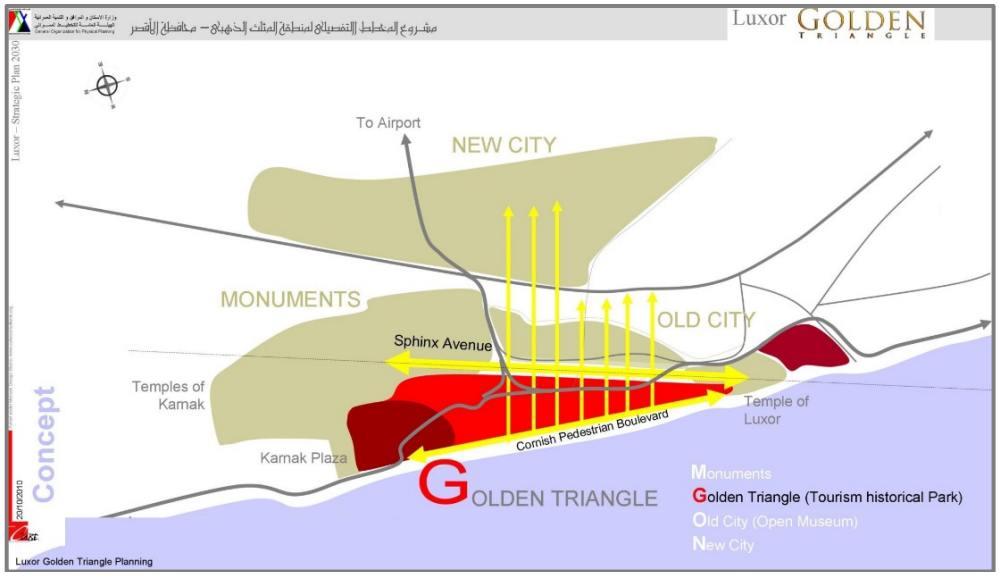

Figure 2: Urban development of Luxor open museum and surrounded sites. *(Source: General Organization for Physical Planning (GOPP) Egypt. https://cuipcairo.org/en/directory/general-organization-physical-planning-gopp.)*

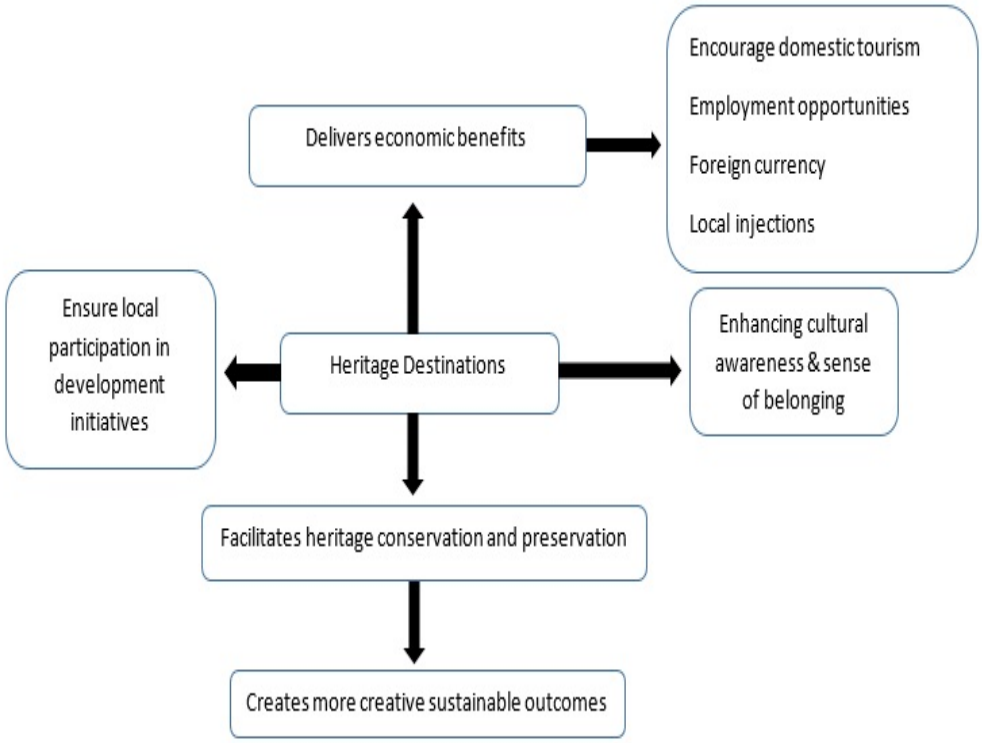

Figure 3: Conceptual framework. *(Source: Adapted from [10].)*

3 METHODOLOGY

This research depends on an inductive approach in which qualitative data is collected to achieve its aim, which is to study a development plan for the city of Luxor, its objectives, and the difficulties that may face in the implementation of this plan. Qualitative data is gathered using focus groups. The focus groups are structured and hold focused discussions among small groups of people. The usage of focus groups holds many advantages, such as being useful for providing in-depth information in a relatively short period [11].

The participants of the focus groups are key stakeholders in Luxor's tourism. They include Egyptian tourism and cultural authorities, including the Egyptian tourism authority (ETA), the Ministry of Culture, which sponsors cultural events through the Cultural Development Fund Sector, the Foreign Cultural Relations Sector, in addition to the Promotion of Cultural Tourism Committee in Luxor, and the Manager of the Karnak Temple, as well as UN-Habitat executive director and foreign tour operators. Accordingly, the focus group sample size of this research is eight focus groups, with which each focus group having five participants.

The data collection took place a couple of weeks after the opening ceremony of the Sphinx Avenue in Luxor, in November 2021. In addition, the analysis of the qualitative data is done using the Nvivo program, in which content analysis is done. Content analysis is a method or instrument used by the researcher, along with other methodologies and tools, as part of an integrated strategy known as the "inventory" approach in media studies [12].

Table 2: Participants demographics.

Focus group	Participants	Gender	Age	Date
Focus Group (1)	Participant 1	Male	43	3 November 2021
	Participant 2	Female	39	
	Participant 3	Male	35	
	Participant 4	Male	37	
	Participant 5	Female	41	
Focus Group (2)	Participant 1	Female	25	5 November 2021
	Participant 2	Male	29	
	Participant 3	Male	33	
	Participant 4	Female	34	
	Participant 5	Male	27	
Focus Group (3)	Participant 1	Male	30	10 November 2021
	Participant 2	Male	35	
	Participant 3	Male	34	
	Participant 4	Male	31	
	Participant 5	Female	30	
Focus Group (4)	Participant 1	Male	23	12 November 2021
	Participant 2	Female	53	
	Participant 3	Male	49	
	Participant 4	Female	18	
	Participant 5	Female	20	
Focus Group (5)	Participant 1	Female	19	17 November 2021
	Participant 2	Female	21	
	Participant 3	Female	22	
	Participant 4	Male	26	
	Participant 5	Female	24	
Focus Group (6)	Participant 1	Male	27	20 November 2021
	Participant 2	Female	28	
	Participant 3	Male	27	
	Participant 4	Male	27	
	Participant 5	Male	28	
Focus Group (7)	Participant 1	Male	50	25 November 2021
	Participant 2	Female	45	
	Participant 3	Male	46	
	Participant 4	Male	47	
	Participant 5	Female	45	
Focus Group (8)	Participant 1	Male	28	29 November 2021
	Participant 2	Male	29	
	Participant 3	Male	36	
	Participant 4	Male	55	
	Participant 5	Male	53	

4 QUALITATIVE ANALYSIS

Qualitative analysis targets answering seven questions, which are the following:

- Q1: What were the specific development proposals in the "Development Plan for the City of Luxor" (CDCL)?
- Q2: How far have the recommended strategies by CDCL been implemented on the ground?
- Q3: What are the coming plans of the Committee for the Promotion of Cultural Tourism in Luxor?
- Q4: How did the reopening of the Avenue of Sphinxes positively affect the tourism sector in Luxor?
- Q5: What are your expectations for the flow of tourism to Luxor in 2022?
- Q6: What are the challenges ahead for local authorities in Luxor in 2022?
- Q7: How can tourist destinations be transformed into hubs of creativity and human ingenuity to achieve the Sustainable Development Goals?

4.1 Focus group systematic data analysis process

The focus group sessions are recorded to aid in the analysis. The focus group data is analyzed using the method of content analysis. This analysis is a systematic approach to gaining meaning from communicated material. The approach seeks to reorganize, classify, and evaluate themes and concepts [13]. Content analysis provides an understanding of the phenomenon. The researcher listened to the recordings and began to take notes on the groups' responses. Codes were attached to phrases, sentences, or whole paragraphs connected to a specific setting. These codes aided in the discovery of themes and patterns of ideas. The researcher identified quotes to facilitate subsequent analysis by identifying all of the text associated with a particular elicitation or a specific question. Then, the researcher constructed a diagram for analysis of the focus groups in a question-by-question format, grouping codes into meaningful clusters while amplifying quotes and finally, describing findings, using quotes to illustrate responses. Therefore, according to the majority of the supporting code, the theme emerged.

After the analysis was done, four main themes were identified, in which each theme consists of different codes. These are themes of development plans for the City of Luxor, coming plans of the Committee of Promotion of Cultural Tourism in Luxor, reopening of the Avenue of Sphinxes, and challenges of local authorities in Luxor.

4.2 Theme of development plans for the city of Luxor

Development plans for the city of Luxor is the first theme identified by the focus groups. This theme consists of four codes, which are: Luxor citizens, completed projects, development proposals, and creativity and human ingenuity.

4.2.1 Luxor citizens

The development of Luxor city could not take place without the contribution of the city's citizens. This could be represented in the following evidence: "The role of Luxor citizens and the business sector will be the foundation for fulfilling the city's long-term ambition for comprehensive development" (Focus Group: 1 – Participant: 1) and "It is necessary to have actual and effective communication and interaction with the people who live in Luxor to implement the future vision and the comprehensive development of the city, and this

development is required at all levels and requirements, including urban, social, economic, and service levels, as well as with international bodies, administrative bodies, and investors participating in the vision" (Focus Group: 1 – Participant: 2).

4.2.2 Completed projects

Luxor city is starting to open new projects related to the development plans, starting by developing the infrastructure, renewing old touristic attractions, and creating new projects. The evidence related to these points is shown in the following quotations: "The infrastructure development of Luxor has also been completed" (Focus Group: 1 – Participant: 2), "The project of restoring the Great Hall of Columns in the Karnak Temple, developing lighting systems, and restoring the 14-column hall of the Great Hall of Amenhotep III and Luxor Temple was also completed" (Focus Group: 2 – Participant: 3), "The event of reopening the Great Sphinx Street in Luxor was to promote Luxor as the largest open museum in the world, and one of the most important achievements of Luxor city development plans" (Focus Group: 3 – Participant: 5), and "There is a project such as a cable car between the ancient temples and tombs in the east and west, to enjoy the magic of Luxor from the sky, along with the special balloon trips" (Focus Group: 3 – Participant: 5).

4.2.3 Development proposals

Other projects are being planned but still do not take place in reality. Examples could be shown as follows: "The environment, whether natural or man-made, has always been the cornerstone of its vision based on travel safety, quality of service, and responsible behaviour. Therefore, one of the development plans was collective transportation lines for citizens between cities in the eastern and western lines of the governorate, with 64 buses per day" (Focus Group: 1– Participant: 1), "Luxor is also planning several future projects on the governorate's property, which it hopes to undertake in the next few years if financial resources or investors are available. Several notable projects are now being developed to benefit the inhabitants of Luxor Governorate in the areas of service, entertainment, and tourism" (Focus Group: 4 – Participant: 5), "The city of Luxor's growth strategy is represented in several projects, including the completion of the 'Revival of the Pharaonic Rams Road' project, as well as the construction and revitalization of Luxor's world-class tourist marinas in the east and west" (Focus Group: 5 – Participant: 1).

4.2.4 Creativity and human ingenuity

Creativity represents the main factor that enhances development and encourages the increase in tourism rates. The evidence for this is represented in the following quotations: "Tourist destinations could be converted to hubs of creativity if we put great attention into developing the arts, cultural and creative industries, diverse expressions, and imagination" (Focus Group: 1 – Participant: 3), "We work to create creative tourism experiences that have the following characteristics: This social dimension is appreciated by tourists looking for vibrant experiences. Qualified consumption, includes experiences that allow tourists to learn new skills. Tourist involvement includes active participation and interaction with the local context and communities, making tourists co-creators of their experience" (Focus Group: 2 – Participant: 2), "The development and urbanization of cities also represent a successful root of creative tourism activities" (Focus Group: 3 – Participant: 1), and "Creativity is emerging as a key element in differentiating a destination's tourist offer and increasing its competitiveness. Therefore, I suggest making cooperation between the governmental and private sector for the aim of developing the tourism destinations and the whole tourist governments" (Focus Group: 4 – Participant: 5), "Managers and policymakers should

recognize that creative tourist experiences are the result of a co-creation process based on creativity, in which all actors must collaborate. Policymakers involved in this process should strive to create a creative local environment and plan initiatives to develop the creative skills of local people and local tourism businesses through activities such as creative development workshops and training courses, among others" (Focus Group: 5 – Participant: 4).

4.3 Theme of the coming plans of the Committee of Promotion of Cultural Tourism in Luxor

The coming plans of the Committee of Promotion of Cultural Tourism in Luxor is the second theme identified by the focus groups. This theme consists of two codes, which are: global coordination and marketing plans.

4.3.1 Global coordination

One of the successful ways of increasing the tourism rate is depending on global coordination. This point is represented as follows: "The committee intends to broaden the Bridge of Civilizations initiative, which invites artists from various markets exporting tourism to Egypt to create artworks inspired by Ancient Egyptian civilization" (Focus Group: 1 – Participant: 1), "Our committee plans to host about eight artists from around the world to work on tourism promotion abroad" (Focus Group: 1 – Participant: 4), and "The committee's coordination with some countries, including Italy, Belgium, France, and Holland, to hold a mini B2B tourism exchange in Luxor is one of the creative sustainable ideas. We are currently arranging with them the idea of hosting a group of tourism companies from each country so that we can create a mini tourism exchange instead of the ones that have been cancelled due to the pandemic" (Focus Group: 3 – Participant: 3).

4.3.2 Marketing plans

The Committee of Promotion of Cultural Tourism in Luxor also depends on different marketing plans to increase the tourism rate, which is shown as follows: "The committee has begun planning events to attract tourists to various Egyptian destinations in general, and cultural tourism in particular" (Focus Group: 3 – Participant: 1), "Due to the city's rapid development, tourism companies altered their tourist programs to extend or expand tourists' stays in Luxor to enjoy the avenue and the city" (Focus Group: 1 – Participant: 2), "Also, learn from Europe's good practices and various tourist destinations that rely on domestic tourism during times of crisis, particularly during the current pandemic, which helped them absorb its negative economic ramifications. Domestic tourism is encouraged through various marketing activities" (Focus Group: 3 – Participant: 2).

4.4 Theme of reopening of the Avenue of Sphinxes

The reopening of the Avenue of Sphinxes is the third theme identified by the focus groups. This theme consists of two codes, which are: tourism in Luxor and the effect of the event.

4.4.1 Tourism in Luxor

The reopening of the Avenue of Sphinxes has had a great effect on tourism in Luxor. This could be represented in the following evidence: "My expectations are very high. I believe that if the rate of spread of the Omicron variant around the world slows, tourist traffic to Luxor could increase by 100% 'sooner'" (Focus Group: 3 – Participant: 4), "I expect cultural tourism to grow more in 2022" (Focus Group: 4 – Participant: 4), and "The city's tourism flow is currently very good. We are seeing for the first time that Russian tourists with a high

spending average are beginning to participate in cultural tourism, which is very important. We should keep in mind that the Russian market has always been known for recreational tourism, but this shift in trends is an encouraging sign" (Focus Group: 5 – Participant: 1), and "Domestic tourism should account for a significant portion of total tourism revenue. In the current winter season, Egyptian tourists' average spending is approaching that of their foreign counterparts. Many Egyptian families are drawn to visit Luxor, where they engage in a variety of tourist activities, including visits to various archaeological sites, which increases their cultural awareness and sense of belonging" (Focus Group: 5 – Participant: 2), "In 2021, Luxor received approximately 2.5 million tourists. Around 97,000 foreign tourists and 36,000 Arab and Egyptian tourists visited Luxor in winter 2021, and tourist visits increased significantly in December and January 2021" (Focus Group: 5 – Participant: 3), "Demand for tourism in Luxor increased ahead of the event, as cultural events are the primary tourism marketing tool and present an opportunity for destination marketers to help position their destination among competitors" (Focus Group: 5 – Participant: 5).

4.4.2 The effect of the event

The opening of the Avenue of Sphinxes has other effects, which could be shown as follows: "The event was covered extensively by 120 international channels as well as 82 journals and magazines. In addition, 65 features were produced on Luxor and its worth, promoting the city as the world's largest open museum. This widespread media coverage resulted in a 28% increase in demand for cultural tourism as well as a price increase of 18%" (Focus Group: 2 – Participant: 2), "The Luxor event is a timely reminder of human civilization's extraordinary achievements, but it is also a reminder of the fragility of our bond with the natural world" (Focus Group: 4 – Participant: 1), "It is important to note that the infrastructure that was built alongside the avenue plays an important role in marketing tourism, particularly in connecting the coastal governorates with Luxor, Aswan, and Suhag" (Focus Group: 4 – Participant: 5), and "The reopening of the Avenue of Sphinxes aids in the operation of effective collaboration among various policymakers, which improves the quality of local and sustainable development policies" (Focus Group: 5 – Participant: 2).

4.5 Theme of challenges of local authorities in Luxor

The fourth theme identified by the focus groups is the challenges of local authorities in Luxor. This theme consists of three codes, which are: training system, prices, and cultural tourism.

4.5.1 Training system

Despite all the development plans that have been implemented in Luxor, a well-established training system is required, especially during the period of coronavirus. This is shown as follows: "The most difficult challenge is maintaining coronavirus precautionary measures. We must complete the training system not only in ministry-controlled facilities but also in one-and two-star tourist facility directly under the control of the local government" (Focus Group: 3 – Participant: 4).

4.5.2 Prices

One of the main challenges that need to be solved is applying more control over prices. The following evidence showed this point as follows: "The main challenge is related to maintaining the minimum prices of hotels" and "One of these challenges is represented by the difficulty in controlling prices" (Focus Group: 1 – Participant: 4).

4.5.3 Cultural tourism

Although cultural tourism is a very good way of attracting more tourists, it is still a serious challenge in Egypt, this is shown in the following quotations: "Additionally, we do not focus on transforming cultural tourism to prioritize quality over quantity and on attracting high-spending tourists back to Luxor" (Focus Group: 2 – Participant: 5) and "The less dependency on domestic tourism represents one of the serious challenges, accordingly we can encourage the domestic tourism if we focus on the cultural tourism" (Focus Group: 3 – Participant: 3).

5 CONCLUSION

Luxor is a great city that introduces the ancient Egyptian civilization region and represents the main cultural tourism destination in Egypt. Luxor holds over 800 archaeological sites and shrines of the most magnificent human heritage. The current research aims to study a development plan for the city of Luxor, its objectives, and the difficulties that may face in the implementation of this plan. The research also studies the reopening ceremony of the Avenue of Sphinxes as a case study of the development plan that was implemented in the city of Luxor, studying the effectiveness of this development plan and studying sustainable creativity in the city of Luxor.

Accordingly, seven main questions have been developed to collect primary and qualitative data through focus groups. A content analysis was done and four main themes were developed with their codes, which are represented as follows: Theme of Development Plans for the City of Luxor (Theme of Development Plans for the City of Luxor, Theme of the Coming Plans of the Committee of Promotion of Cultural Tourism in Luxor, Theme of Reopening of the Avenue of Sphinxes and Theme of Challenges of local authorities in Luxor), Theme of the Coming Plans of the Committee of Promotion of Cultural Tourism in Luxor (Global Coordination and Marketing Plans), Theme of Reopening of the Avenue of Sphinxes (Tourism in Luxor and The Effect of the Event) and Theme of Challenges of local authorities in Luxor (Training system, Prices, and Cultural tourism).

6 IMPLICATIONS AND RECOMMENDATIONS

The paper aims to study creative sustainability. The results indicated that this approach may greatly assist in the evaluation of priority proposals and projects with the shortest to ensure consistency, directions, results and recommendations across all planning and development efforts. Based on the results, the recommendations were made as follows:

- The need for interaction and use of the residents of Luxor by governments and decision makers for development projects.
- This recommendation is for decision makers and governments to complete the initial projects in the development stages before starting actual developments, for example completing the infrastructure development first before starting new projects.
- The necessity of having proposals for development, its dimensions, and its cost, to study it well at the beginning before starting it.
- Attention should be paid to creativity, as creativity represents the main factor that enhances development and encourages the increase in tourism rate.
- Interest in including a number of international cooperations, because it helps to include the largest number of different cultures in development, and each country will encourage its citizens to come and see these developments.
- Developing plans for global and local marketing of developments also helps the coming plans of the committee of promotion of cultural tourism in Luxor.
- Opening new projects or developing closed projects is an important reason for the increase in the number of tourists in the country, as happened in the project to reopen the

Avenue of Sphinxes, so decision makers should pay attention to the redevelopment of existing projects before starting new projects.

- Paying attention to international stations to transmit all the developments that occur, helps to increase the awareness and knowledge of foreigners and tourists about these developments, and increases the percentage of tourism.
- A well-established training system is required for participants on development projects.
- Develop a specific budget for development projects to study the cost and search for ways to finance these projects, to reduce the risk of increasing prices and costs.
- To give domestic tourists the same attention that is given to global tourists, we can encourage the domestic tourism if we focus on the cultural tourism.

7 REFERENCES

[1] Kamar, G. & Ismail, T., Urban regeneration challenges of heritage cities using GIS (Luxor City Case Study). *First International Conference On Towards a Better Quality Of Life*, 24 Nov., 2017. DOI: 10.2139/Ssrn.3171835.

[2] Hesham, E.S. & Baller, I., Changing perspectives on responsible heritage site management: The case of Luxor City, Egypt História. *Questões E Debates*, 66(1), pp. 141–165, 2018.

[3] United Nations, Sustainable development goals. https://www.un.org/sustainabledevelopment/.

[4] World Tourism Organization and Organization of American States, Tourism and the Sustainable Development Goals: Good practices in the Americas, UNWTO: Madrid, 2018. DOI: 10.18111/9789284419685.

[5] Jaafar, M., Noor, S.M. & Rasoolimaneshi, S.M., Perception of young residents towards sustainable conservation programme: A case study of the Lengong world cultural heritage site, 2015.

[6] Mróz, A. & Ocetkiewicz, I., Creativity for sustainability: How do Polish teachers develop students' creativity competence? Analysis of research results. *Sustainability*, **13**(2), p. 571, 2021.

[7] Duxbury, N., Bakas, F.E., Vina-Gre De Castro, T. & Silva, S., Creative tourism development models towards sustainable and regenerative tourism. *Sustainability*, **13**, p. 2, 2021. DOI: 10.3390/Su13010002.

[8] d'Orville, H., *The Relationship between Sustainability and Creativity*, vol. 4, 2019. http://Cadmusjournal.Org/.

[9] Al-Ababneh, M.M., Creative cultural tourism as a new model of the relationship between cultural heritage and tourism. *International Journal of Hospitality and Tourism Studies (IJHTS)*, 2020. https://www.refaad.com/Views/IJHTS/Home.Aspx.

[10] Hawkins, H., Geography and art. An expanding field: Site. *The Body and Practice. Prog. Hum. Geogr.,* **37**(1), pp. 52–71, 2013.

[11] Dong, Factors affecting tourist destination choice: A survey of international travelers to Hanoi, Vietnam. National Economics University, Vietnam. *Journal of Economics and Development*, **19**(1), pp. 77–92, 2017.

[12] Gundumogula, M., Importance of focus groups in qualitative research. *International Journal Of Humanities And Social Science (IJHSS),* Center For Promoting Ideas (CPI), USA, **8**(11), pp. 299–302, 2020.

[13] Krippendorff, K., *Content Analysis: An Introduction to its Methodology*, SAGE Publications, 2018.

[14] Corbin, J. & Strauss, A., *Basics of Qualitative Research*, SAGE Publications: Thousand Oaks, CA, 2015.

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ENVIRONMENTALLY RESPONSIVE DESIGN IN BRITISH COLONIAL ARCHITECTURE WITHIN THE MEDITERRANEAN BASIN: THE CASE OF THE PRESIDENTIAL PALACE OF CYPRUS

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ABSTRACT

The conservation of historical buildings is a highly sustainable practice. Among others this is a process of reuse and preserving cultural values and past knowledge, and understanding the evolution of history and architecture. Another sustainable aspect of historical buildings is the adaptability to local climatic and geomorphological conditions through the incorporation of various environmentally responsive design features. To achieve the sustainable conservation of historical buildings the environmental design elements need to be identified, preserved and even reinforced. This paper presents an in-depth investigation of an iconic historical building – the Presidential Palace of the Republic of Cyprus – which was constructed as the government house when Cyprus was a British colony. Incorporating local construction techniques, materials and forms alongside British architectural elements, the building under study is representative of British colonial architecture on the island. The aim of the investigation was to identify the architectural and bioclimatic elements of the building that should be preserved, restored and reinforced. Additionally, other similar local colonial buildings are presented and compared alongside the Presidential Palace, to identify typical architectural and bioclimatic elements in the colonial architecture of the island. These elements include the configuration of semi-open and open spaces, as well as construction techniques, materials, layout arrangements and building shell opening characteristics. The research incorporates findings from existing literature, as well as media, photography and governmental archives. The findings of this research may be applicable in other areas of common climatic conditions, where similar typological and constructional characteristics are to be found. These findings can assist the conservation and energy retrofit actions of historical buildings.

Keywords: environmentally responsive design, environmental conservation, historical buildings, bioclimatic elements, Eastern Mediterranean, sustainability, colonial architecture.

1 INTRODUCTION

The sustainability aspect of historical and vernacular building conservation, apart from its social and cultural perspective, is often recognized through the process of reusing existing resources or through a building's small energy footprint due to the utilization of local natural materials of low processing value. The sustainable aspect of their adaptability to the local climate and geomorphological conditions is often neglected. This adaptability is achieved through the incorporation of various environmentally responsive design features in the historic and traditional settlements. Neglecting these environmental design elements during the conservation process can result in decisions that reduce or even cancel the impact of such passive design features on the indoor environmental quality, i.e. thermal and visual comfort, indoor air quality (IAQ) etc. [1], [2]. It should be noted that the utilization and enhancement of these environmentally responsive features could have a significant impact on the energy demand of these buildings.

Despite the fact that many studies have identified and assessed the environmentally responsive features of vernacular architecture [3], [4] proving its ability to adapt to the local climate, yet similar studies on buildings of colonial architecture are very limited. Colonial

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architecture worldwide may be considered part of the local and regional heritage. Unlike vernacular architecture, colonial buildings were most often designed by a specific person and they tend to incorporate specific ideas and symbols connected with the aspirations of the conquerors. British colonial architecture is an amalgam of the dominant architectural style of that time in Britain, the center of the empire, confirming the British presence and role in the area and local traditional architectural forms [5], [6]. This fusion in architectural styles was also influenced by the fact that the buildings were designed primarily by Britons and constructed by local builders [5], [6]. The choice of using local labor and materials was for time-effectiveness and cost reduction. It also presented an image of an administration that creates jobs and supports the local market, as was mentioned in some Cypriot newspapers [7].

Cyprus was one of the last colonies to be ceded to the realm in the Mediterranean. In 1878 Cyprus was leased to Britain from the Ottomans through a secret deal to support the latter against Russia. Cyprus was to be under British administration but remain an Ottoman territory and pay a yearly tribute to the Sultan, until 1914. With the Ottoman Empire siding with the Central Powers during World War I, Britain annexed Cyprus and declared it a British protectorate. In 1925 Cyprus was formally declared a Crown Colony. As in other places of the world, Cyprus colonial architecture is characterized by a mixture of styles, some imported by British and some found in local vernacular architecture [6]. Moreover, due to the small size of the colony and its uncertain status, local colonial architecture is characterized by simplicity and functionality due to the need for fast construction and low cost [6], [8].

Colonial architecture often incorporated local techniques and architectural features for climatic adaptation. The climate of Cyprus is characterized by long periods of clear skies, even during winter, intense solar radiation, high summer temperatures and moderate winters. The British administration officers had realized through living in many different areas of the world that imported architecture had often proved inappropriate [5]. Studies from different regions of the world concluded that local architectural practices through a process of adaptation and improvisation incorporated bioclimatic features of vernacular local architecture [9], [10]. The aim of this paper is to explore the environmentally responsive design aspects of colonial architecture in Cyprus through the assessment of selected colonial administrative buildings. Moreover, the study aims to identify the architectural and bioclimatic elements of the British colonial buildings on the island, which should be preserved, restored and reinforced. This is the first study to investigate the environmentally responsive design aspect of the colonial buildings of Cyprus.

2 METHODOLOGY

The research presented in this paper includes an investigation and analysis of seven colonial buildings through existing literature, media, photography and governmental archives. More specifically, an in-depth investigation of the Presidential Palace of the Republic of Cyprus, which was constructed as the Government House when Cyprus was a British colony, is presented. Through this investigation the bioclimatic elements introduced in the building design are identified. Then, six additional iconic British colonial buildings in the four major cities of the island were assessed with regards to their bioclimatic elements. This study concludes with a comparison between the seven representative buildings showing common and typical environmentally responsive architectural elements. The selection of which colonial buildings to study was based on three criteria: (a) design history – should be designed and constructed by the British colonial administration; (b) use – should accommodate government services; and (c) period of completion – before WWII. The design and supervision by British engineers minimized the contribution that local master builders or

designers may have had on the final decisions concerning building design. The accommodation of administrative services in the selected buildings addressed similar needs by the building design in all cases, i.e. same working hours, office room dimensions, lighting and ventilation need, waiting areas for the public etc. Examples housing other building uses were not included in order to homogenize the sample. Regarding the time period, it was noted that after WWII, reinforced concrete constructions, along with the Modern Movement aesthetics, gradually became predominant in Government buildings [6]. As this paper focuses on the colonial architecture characterized by eclecticism merging dominant British styles and local traditional architectural elements, buildings influenced by the Modern Movement were excluded.

3 PRESIDENTIAL PALACE (PP): A REPRESENTATIVE CASE OF TYPE

Soon after the British came to Cyprus, the Public Works Department (PWD) was created and staffed by British Engineers [8]. British administration initially focused on the accommodation of British officers, troops, and the Governor. The Presidential Palace, or Government House, as it was called during the British rule, being the house of the Governor of the colony is one of the most characteristic colonial buildings on the island, infused with symbolism and local architectural forms. The history of this building is interconnected with the history of Cyprus from the beginning of British rule until today. The building site is a small wooded hill south of the Walled city of Nicosia, with the Pediaios River grazing its western edge. The first British High Commissioner of Cyprus, Sir Garnet Wolseley, chose this location instead of a house intended for him inside the city walls, as he preferred to live outside the "indigenous city" in a segregated area [8]. The pleasant microclimatic conditions especially during summer, with unobstructed winds filtered by the vegetation, was probably another reason for his choice. The immediate need for his accommodation was answered with the request for a prefabricated Government House imported from England [8].

The house was timber framed, appropriate for tropical climates and intended as a temporary solution and this prefabricated structure remained as the Government House until 1931. The Governor, Sir Ronald Storrs, envisioning the construction of an impressive colonial building, commissioned the design to Austen St Barbe Harrison who had just designed the Government House in Jerusalem. However, in 1932 Storrs was replaced by Sir Reginald Stubbs who considered Harrison's proposal too grandiose and costly for the economy of a small colony like Cyprus. He cancelled Harrison's contract and assigned the design of the "New Government House" to Maurice Webb, of the London office "Sir Aston Webb & Son". The construction of the building began in November 1933 and was completed in the middle of 1936. The construction was under the PWD and J. V. Hamilton, an architect sent from London, was assigned to supervise the construction. Interestingly, even though Stubbs played a leading role in the building's design, he was replaced by Sir Richmond Palmer before the building was completed who then became the first resident governor.

The design of this building expresses the thinking of the times with regards to colonial architectural style. The building incorporates arcades copied from an 18th century monastery, a four-story tower which references the medieval castle of Kolossi, Byzantine and Ottoman domes, column capitals from Byzantine or Frankish buildings found in Cyprus, doors that were replicas of those to be found in ancient monasteries of the island, British glazed doors and windows, and neo-classical symmetric layout were introduced in the design [6], [7]. The amalgamation of forms located in older structures on the island, from different time periods and architectural styles, made this building an indicative example of the colonial administration intention to develop a "Cypriot" style.

The building has a U-shaped layout with building volumes around a central courtyard open toward the south. The north wing is two-story with a central four-story tower facing the courtyard and a projecting two-story central building volume of ashlar stone on the north (Fig. 1(d)). This projecting volume has an arcaded porch on the ground floor leading to the main building entrance and a room fronted by an arcade on the upper floor. The east and west wings are single-story. The two-story volume is covered by a pitched roof, while the single-story wings are covered by hipped roofs. The roof tiles are made of local clay. The layout is characterized by symmetry along a north–south axis with the imposing entrance placed at the center of the north elevation. The ground floor accommodated the Governor's office, the Council Chamber and rooms where official balls and dinners were held, while the living quarters for the family and guests were on the upper floor.

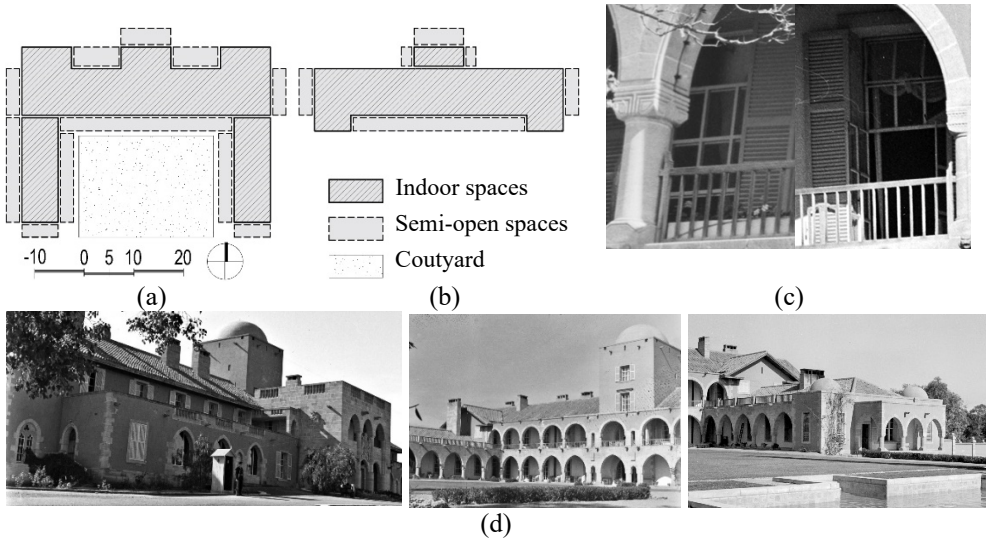


Figure 1: Government House schematic plan views. (a) Ground floor plan view; (b) First floor plan view; (c) Left: double-hang window – leaves in center position*. Right: door – top window slightly open**; and (d) Government House photographs from the 1950s*. *(Source: * PIO, Photo by Felix Yaxis; ** PIO.)*

3.1 Bioclimatic elements

The environmentally responsive design features found in the building can be classified in five categories: the materials, the cooling strategies, the heating strategies, the strategies for microclimatic regulation and the strategies to improve indoor daylighting.

Regarding building materials, the structure is of load bearing stone masonry, 50 to 60 cm thick. This massive building envelope is particularly appropriate in climates with high diurnal temperature variation such as the Mediterranean [2], [3], [11]. The building envelope absorbs and stores heat during the hours of sunshine, while at the same time ensuring the minimum thermal influence to the indoor environment. During the winter season, the thermal mass minimizes thermal losses while also acting as a heat storage element during the daytime and for heat supply during the night. Similarly, during the summer heat transfer to the indoors is delayed and the highest indoor temperatures occur with a time lag, compared to the outdoor

environment. This time lag is highly significant as the outdoor temperature decreases as time passes. If this strategy is combined with natural ventilation during nighttime, when the outdoor air is significantly cooler, the building envelope and associated spaces are thermally discharged and the same process is being repeated the following day [11]. Moreover, in the exterior the high thermal inertia of the soil keeps the temperatures lower during summer, while paved areas absorb radiant heat, thereby increasing the external temperature.

The heating strategies identified in the building are presented in this paragraph. The bioclimatic orientation is observed in the layout composition. The main living rooms are placed on the south side of the building, while the north side accommodates secondary spaces like corridors and restrooms. Moreover, on the north side of the building there are two semi-open spaces with pointed arches, one on each side of the entrance, that were converted into cloakrooms with sliding windows. South openings may increase solar gains in building interiors and ensure direct heat gains. Indirect heat gains are achieved when the massive structure absorbs solar radiation throughout the day and returns it to the interior spaces with a noticeable time lag [2], [3]. This layout composition allowed for utilization of winter solar gains and minimization of time spent in the colder north spaces.

The following paragraphs present the cooling strategies identified in the Presidential Palace. The building wings are elongated, with stone arcades located primarily around the central courtyard. The south side of the two-story wing is fronted both on the ground and on the upper floor by arcaded verandas. The south sides of the single-story wings initially did not include covered spaces. In later years, arcaded semi-open spaces were added on these sides, as shown in photographs from the 1950s (Fig. 1(d)). Even though a south orientation is beneficial during winter, during the summer different shading elements need to be added to minimize solar gains. South semi-open spaces shade the building envelope during summer, when the sun is at a higher position, while allowing direct solar radiation to reach the building during winter, when the sun is lower [2]. The west and east sides of the building wings are also mostly fronted by arcaded semi-open spaces. These spaces are also beneficial on west and east sides, especially if they are arcaded so as to minimize the solar radiation even when the sun is lower due to increased wall area. These semi-open spaces work similarly to the vernacular bioclimatic element of *iliakos* and even retain its proportions [2], [3]. Eastern semi-open spaces are not placed on the east single-story wing probably because this was the least visible side and it accommodated rooms for the staff. Moreover, no overhangs were placed on the east and west sides of the rooms located in the upper floor of the entrance building volume. In a letter dated 2 April 1937 [12], Sir Palmer, complains about the overheating of these rooms due to solar radiation and mentions the addition of verandas that did not “spoil the appearance and harmony of the façade” on the west and east sides (Fig. 1).

The building fenestration was of steel framed casement glazed doors with a top window and double-hang windows (Fig. 1(c)). The material, proportions, and opening mechanisms are of British origin as they are not found in local traditional architecture. Other bioclimatic features to be found on the building, that is also found in the vernacular architecture of the island, are the window shading devises. On the ground floor the glazed windows and doors are fitted with shading devises with the exception of the openings in the semi-open spaces. This underlines their role as devises that protect from solar radiation, but also from other weather elements such as rain or strong winds. All windows of the upper floor are fitted with shaders, probably for lighting control and privacy reasons. Shaders are also placed on the north openings. This decision offered an extra protection from the strong and cold north winds. The shaders were primarily operable, timber shutters with louvers while a few, on the more elongated windows, were timber lattices. Even though the louvers provide shading, they do not block the light completely and simultaneously allow for air circulation.

Another bioclimatic strategy identified in the building, is natural ventilation. Natural ventilation can be wind-based, entering through a window on the windward side of the building and exiting through another window on the leeward side. Thus, windows on different building sides are needed to achieve cross-ventilation. Even though many windows and doors are placed in all the external walls of the building under study, only a few rooms can benefit from cross-ventilation. This is because most rooms have openings only on one side, with an interior corridor providing room access on the opposite side. Since many openings are also placed along the corridors, cross-ventilation can be achieved through the opening of the internal doors. Natural ventilation can also be achieved through buoyancy-driven ventilation (stack effect). In the building, stack-ventilation can be achieved through the top windows or through the placement of the leaves of the double-hang window in the center position. Moreover, natural ventilation is achieved through a system of in-wall ducts where the warm foul air rises naturally and expelled to the outside environment through vents in the roof stacks. This in-wall system for improving the indoor air quality of the rooms, was imported from Britain.

The design of the roof could also have a significant impact on the indoor environment. Initially, the rooms had high ceilings allowing for better air distribution. Moreover, the roof structure was covered by the placement of a wooden ceiling. This resulted in a closed space that worked as a buffer zone between the outdoors and indoors, increasing the insulating properties of the roof. In some cases, like those at the Government House, the roof was naturally ventilated. This exfiltrated any warm air trapped in the roof and induced cooling of the roof space and its structural components. Finally, local traditional materials, such as limestone and gypsum-based plasters are used in light colors, reflecting thermal radiation and thus reducing the radiation absorbed by the building envelope. This reduces the chance of overheating during the summer.

With regards to strategies for improving microclimatic regulation, one of the most common elements found in vernacular architecture in Cyprus is the courtyard [3]. The Government House, as mentioned above, is placed around a central courtyard open to the south. The courtyard is covered with grass, shrubs and a few trees. The solar gains noted at the courtyard are reduced, while if combined with vegetation, the microclimatic conditions are highly improved. More shading is provided to the building and the courtyard floor thereby reducing temperatures. The thermal mass of the surrounding surfaces also moderates temperatures during summer and winter, while vegetation moderates the humidity level, dust and other weather elements. The south orientation of the courtyard allows for south, east and west oriented spaces looking towards the courtyard. The overlook towards the courtyard, a private area of the building, allows for an increased number of openings permitting high levels of indoor daylighting and natural ventilation. Moreover, the improved microclimate also effects the indoor spaces in a positive way.

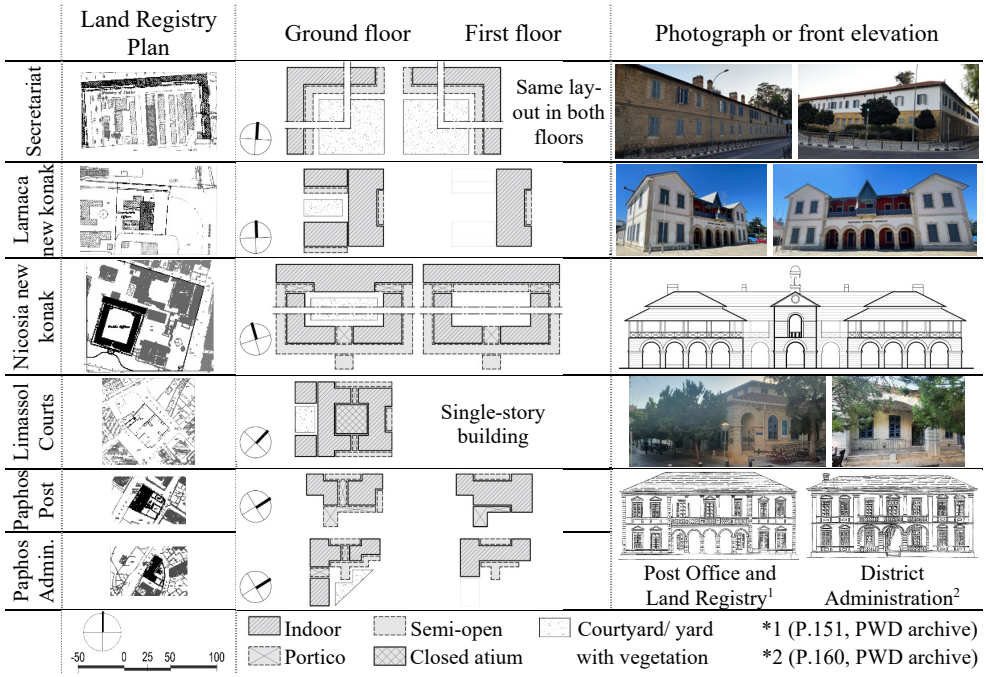
Finally, based on the building's design high levels of natural lighting reach the indoor spaces through a significant number of glazed openings. Moreover, the openings are very high and they incorporate top windows. Vernacular architecture often underperforms in daylighting levels, as cultural and construction restrictions resulted in fewer and smaller openings. During the British rule this changed and high windows were incorporated overlooking all directions, with much more importance placed on building façade composition towards public roads. The need for high daylighting levels is expressed by Palmer who requested the extension of the east and west halls through the incorporation of ground floor east and west verandas [12]. The purpose of this modification was for increasing the room area and for the benefit of the natural lighting of these spaces, which opened solely on the east and west sides.

4 DESCRIPTION OF SELECTED COLONIAL BUILDINGS

This section presents the analysis of six colonial buildings in Cyprus, other than the Government House. The Secretariat and the "new" Konak in Nicosia, the "new" Konak in Larnaca, the Limassol Law Courts, the Paphos Post Office and Land Registry building and, finally, the Paphos District Administration building. These buildings located in the four major cities of the island were constructed from 1882 to 1937. District Administration buildings were called "Konaks" during the Ottoman period, thus many of the buildings under study were known as "New Konaks". The analysis includes a brief presentation of each building's history, typology, site location and building layout. The analysis also includes the identification of the building's environmental passive design strategies.

Many architectural and bioclimatic design features are common in all case studies. They are single or two-story, stone-built structures with inclined roofs. All colonial buildings are made of similar materials, specifically load-bearing, thick, stone-made walls. The indoor spaces have high ceilings and the roof is always pitched and covered with local clay tiles. In some cases, the roof is hipped and in others is gabled but always sealed with a wooden ceiling. Finally, the fenestration is always fitted with external operable timber louvered shutters. In some cases, the louvers are adjustable allowing the building occupant to adjust the rotating angle of the louvers.

Table 1: Positioning in site, floor layouts and views of the buildings under study.



4.1 Secretariat Building, Nicosia (Sec.)

The Secretariat is the first permanent building to be constructed in Cyprus by the British administration [6]. The building was designed by the Government Engineer William Williams in 1880 as barracks to accommodate the "Cyprus Pioneer Corps". It is located in a

large plot of land on the Southwest of the old city of Nicosia, on the way from the city to the Government House. The building layout is U-shaped enclosing a parade ground. More specifically, the U shape results from two mirrored L-shaped two-story wings. The small distance between the two wings creates a northern entrance way to the central yard. The internal area of the building is about 2,400 m^2 making it the largest of the buildings under study. The construction took place between 1880 and 1882 and it was completed in phases. The west L-shaped wing was the first to be constructed [6]. Before the completion of the building the "Cyprus Pioneer Corps" was disbanded. Consequently, it was decided that the newly build construction was to be adapted to accommodate colonial administration uses like the Secretariat offices, the Treasury and the Government Engineer's Department, the predecessor of the PWD [8]. The architectural design is simple, well-proportioned and focusing on function and environmental acclimatization.

With regards to the bioclimatic design strategies, the orientation of the building layout is clear with the building blocks positioned on the North, East and West sides of the central yard leaving the South side open. The central yard cannot be considered as a courtyard with regards to bioclimatic behavior, as due to its great size any effect of the surrounding volumes on the microclimate of the yard is diminished. The building consists primarily of ashlar load-bearing, stone-made walls. Probably due to lack of funds, the upper floor of the north-eastern side of the building was made of lightweight timber-framed construction with stone rubble infill and gypsum plaster rendering. The building blocks are two-story and consist of rows of shallow depth rooms with semi-open spaces at the side of the yard, southward, westward and eastward and they were used both for building circulation and for sun protection. The semi open spaces of the ground floor are pointed arch cloisters and on the upper floor they are lightweight verandas with timber posts supporting the roof. The arches increase the wall area providing more shade while the roof of the upper veranda is fairly low to minimize the direct sunlight that reaches the rooms. Additionally, the architectural element of in-wall ventilation is introduced in this building. In this case, the system includes a fresh air inlet on the exterior wall near the ceiling with perforated terracotta or cast-iron grilles on the outside and adjustable timber louvers on the inside. At the same time, foul air is exfiltrated through an internal opening with louvers near the ceiling connected to terracotta pipes located within the interior wall. The warm foul air rises naturally through the pipes and is expelled to the outside environment through the openings of a ventilation stack [8].

4.2 "New Konak" of Larnaca (KL)

The "New Konak" of Larnaca accommodated District Administration, the Land Registry and the Post Office. It has a U-shaped layout formed by a two-story east wing and two single-story wings on its north and south sides. The two-story wing was built in 1882, along with the harbor works, by the Government Engineer Samuel Brown. The other two wings were added in 1915 by the PWD [6], [8]. The north side of the ground floor was occupied by the Land Registry offices, while the south side was occupied by the Post Office. The District Administration offices were located on the upper floor. The architectural design of the building is very characteristic of British colonial architecture as it follows a pattern for public buildings developed in other British colonies as well [6]. Specifically, the building's main façade is a composition of two gabled building volumes, one at each end, and a central building volume with a porch of semi-circular stone arches on the ground floor and a lightweight colonnade of timber posts on the upper floor. The symmetry in both the layout and the façade of the building is explicit. The staircase is in the center of the two-story wing

in an entrance area that served as a circulation distribution element towards the other rooms of the building, like a "closed portico".

As mentioned above, the building layout is U-shaped forming a central courtyard open only on one side. In this case, and in contrast to the first two buildings under study, the building volumes are on the north, east and south sides of the courtyard leaving the west side open. The orientation of the building was probably defined by of its relative position to the seafront. Nevertheless, the bioclimatic principles are clear in the decision to create covered spaces on the south of the one-story wings. Specifically, there is a semi-open arcaded space in the north building volume towards the courtyard and an iron veranda projecting southward of the south building volume. The iron veranda unfortunately no longer exists, but it can be seen in an old postcard from 1931 and it is also mentioned on the ground floor plan of the 1915 extensions [6]. In the same postcard the rich vegetation of the courtyard is also visible.

4.3 "New Konak" of Nicosia (KN)

This building was constructed in 1904 on the land where the Lusignan Palace once stood. Any proposals with a view to preserving the old Palace were denied and it was decided to construct a completely new building which would project a British image, cost less and be more functional [6], [8]. So, in 1899 Charles Bellamy, Director of PWD at the time, designed this building based on a previous scheme by William Williams. For reasons of economy stone rabble from the older demolished palace was used for the new structure. The "new" building housed the Law Courts, the Post Office, the Land Registry and the Commissioner's office.

The building layout is a quadrangle with a central courtyard covered by rich vegetation. The layout is symmetrical, especially with regards to the front façade. The building façade and side elevations are characterized by a continued stone-made arcade on the ground floor and a lightweight covered veranda on the upper floor. The arcade consists of semi-circular arches on stone piers and the upper veranda is covered by a lower separate hipped roof supported by pairs of timber posts that correspond to the piers below. To give a central focus, a two-story stone porch is projected at the center of the façade.

The bioclimatic aspect in the design of this building is explicit through the positioning of the semi-open spaces and the low-ceiling, verandas. The building façade corresponds to the south side of the courtyard, the side elevations to the east and west sides while the back of the building faces north. The south, east and west sides are clearly symmetrical, with covered open spaces on the building exterior, thereby protecting the internal spaces from intense solar radiation. This is not repeated on the interior perimeter of the courtyard, as the vegetation provides adequate protection from the east and west sun. It is interesting to observe that the layout of the north building wing differs compared to the other three. No covered space is added to the exterior side of this wing probably because it is on the north and thus does not need any solar protection. Moreover, on the south side of this wing a partly closed corridor is added on the ground floor while on the upper floor there is an open colonnade. The south side of the ground floor is fairly protected by the vegetation while the upper floor gains a south facing covered veranda. In this building we observe another bioclimatic element, the "portico", a transitional space which connects the public street with the building circulation spaces. In this case, "porticos" are found in the south main entrance to the courtyard and in the entrances from the west and east sides. Moreover, a ventilation turret with a weather vane on top is placed in the center of the south wing's main roof, thus concluding that stack ventilation strategies are incorporated to the building to exhaust foul and warm air and increase air circulation. Finally, the louvers of the window shutters are adjustable. The shutter's frame is divided in three parts by height, with horizontal louvers in each part. In the

highest part the louvers remain fixed while in the two lower parts the louvers are adjustable through central timber rods that connect and control the louvers of each section.

4.4 Limassol Law Courts (LLC)

This is another building designed by William Williams and constructed by the PWD. The construction was completed in 1911 to accommodate the District Court. The initial layout was a quadrangle with rooms around the Main Court Chamber and semi-open spaces in part of the front façade and side elevations. The single-story building has a hipped roof with a separate elevated hipped roof above the central chamber. Operable windows are placed on the walls that support the elevated roof. Some extensions and modifications took place in 1928 based on plans by Joseph Gaffiero of the PWD [6]. Two blocks were added on the rear view of the building, one on each side, forming a small courtyard. The front view is characterized by symmetry with a central arcaded porch, covered by a wave-form pediment, two identical building volumes on each porch side and two identical arcades at each building end. The arcades and porch consist of semi-circular arches on stone piers.

The building façade is orientated towards the north-east. The building was placed relative to the two vertical sides of the plot and faced the main road. Thus, the layout was highly affected by the existing public roads and the plot shape. Consequently, the semi-open spaces are to the north-east, south-east and north-west. Even though they offer protection from east and west solar radiation, the decision of their positioning, especially of the front porch, was probably defined by the public road. The extensions of Gaffiero formed a south-west courtyard that, based on old photographs [13], was covered with vegetation. Three different louvered shutters are identified in the building, two adjustable and one fixed. All the shutters' timber fames are divided in three parts height-wise, with horizontal louvers in each section. The louvers on the north side are fixed while the louvers on the side windows are adjustable. The louvers on the front of the building have a circular upper part with fixed louvers, a lower part with louvers adjusted by timber rods and a middle part that can be opened separately from the rest of the shutter, which also contains adjustable louvers. The choice for the front shaders was probably due to privacy concerns. The workers could open a smaller higher part of the shutter introducing daylight, while remaining unseen from the public road. The fixed louvers on the back were chosen either for reduced cost or because during the time of the extensions the fixed louvers were more common. Another bioclimatic element is the "portico" which corresponds to the passages from the side arcades to the central Chamber. The final bioclimatic aspect of the design is the elevated central roof with operable windows. In many old photographs [13] the windows are wide open to allow the warm air to be dissipated thereby increasing air movement and replacing the indoor air.

4.5 Paphos Post Office and Land Registry building (PPO)

On a hill overseeing the sea, Paphos Post Office and Land Registry building and Paphos District Administration building that were constructed during British rule stand close to each other along Nikodemos Mylonas street in Paphos. In 1918 the decision for the construction of a new building in the place of the "old konak" to accommodate the Post Office and the Land Registry was taken. The new building featuring a colonial style of architecture was designed by Joseph Gaffiero and was completed in 1919 [8]. The building is located on a privileged yet sloping site rather limited in size and irregular in shape. Its two building sides are along the plot limits and only the two sides along the public roads can have adequate number of openings.

This colonial building is characterized once again by an imposing symmetric façade. Two-story building volumes are placed at each end of the façade and a recessed section fronted by semi-open spaces is placed in the center. The ground floor of the central section is fronted by an arcaded porch of five semi-circular arches supported by piers and on the upper floor by a colonnade of Tuscan columns. The fenestration is freestone-framed with neo-classical pediments. The details and composition of this façade resembles a Renaissance building along with green-shade timber louvered shutters fitted on the stone-framing of the fenestration, for local distinctiveness. This symmetry is not consistent in the building layout. This was a result of the irregular shape of the site along with the influence of colonial layout design – that often introduced the element of an all-round veranda [6], [8]. On the ground floor a secondary arcaded porch was introduced at the side elevation and a portico was located at the back leading to the staircase. Due to the limits of the plot no openings could be introduced to the back wall or the side walls resulting in a long corridor open only on one side. This corridor is also connected to the front porch through a portico. On the upper floor, only the front semi-open space is repeated. The building façade is oriented towards the west-northwest while the other building side adjoining the street faces north-northeast. The semi-open spaces protect the main building mass from east and west solar radiation and create comfortable exterior-yet-covered public reception spaces. With regard to the shutters, the two thirds of the louvers are adjustable. Nevertheless, there are no south openings, limiting the bioclimatic advantages of south oriented openings, especially when this fact is combined with the high thermal mass of the building envelope. Moreover, the absence of openings on two sides of a deep layout result in some spaces that are underlit and under-ventilated. In this case, the existing street layout was a primary factor in affecting the building design, while the bioclimatic considerations were seconded.

4.6 Paphos District Administration (PDA)

The second building of this complex, housing the District Administration, was also designed by Gaffiero and was completed in 1921, soon after the Land Registry and Post Office building [6], [8]. This structure is also in a corner and sloping site, rather limited in size and with an irregular shape. However, in this case three of the plot sides are adjacent to a road while the forth faces another building plot owned, at the time, by the British administration, thereby, allowing for window openings on the fourth side of the building as well. Many similarities can be found between Paphos Post Office and Land Registry building and Paphos District Administration building designed by Gaffiero, especially with regards to their impressive façades. The architectural components of the façades and their dimensions are very similar. The ground floor central porch includes three elongated semi-oval arches supported by stone piers and the upper floor is supported by a colonnade of Tuscan columns aligned to the piers below. Another difference in the detailing is found in the window pediments which are curved rather than triangular. The site limitations affected the layout of this building too, yet more symmetry is found in this case. The layout is L-shaped, following the shape of the site. The main entrance, a central portico and the monumental staircase, which is projecting beyond the back of the building, are placed along a central axis. Through the L-shaped layout the round corner of the site encloses the yard, overlooked by the back offices. The façade of the building is oriented towards the west-northwest and the side wing towards the south-southwest, leaving the back yard open to the southeast. Additionally, semi-open spaces facing the yard are located on the ground and upper floors protecting the building from the south and east summer sunlight. The upper floor of the side wing covers only a part of the south side, in contrast to the ground floor which extends to the opposite plot limit. The lower height

of the southern wing allows more direct solar radiation to reach the building envelope during the winter, while the back semi-open spaces protect the building from overheating during the summer. Openings in the rooms ensure adequate natural light and ventilation. Again, two thirds of the louvers are adjustable using central timber rods.

5 RESULTS, DISCUSSION AND CONCLUSIONS

Environmentally responsive design in colonial architecture of Cyprus is fairly evident as all the buildings investigated incorporate at least 14 of 21 bioclimatic features identified in the study. 11 of 21 bioclimatic elements are incorporated in all the buildings under study. The features related to materiality are incorporated in all buildings. Additionally, the cooling strategies are dominant, while heating strategies are few. This can be explained by the prevalent warm climate conditions in Cyprus. With regard to the heating season, it should be mentioned that fireplaces were introduced in all buildings. The building with the most bioclimatic features is the "new" konak in Nicosia with 20 of 21 elements and second with 19 of 21 elements is the Government House. Many elements were identified in all the buildings investigated, like east-or-west-facing verandas, window shaders, cross ventilation, high thermal mass, closed pitched roof, high ceilings, light colored materials on exterior surfaces and an increased number of external openings. South openings and yard with vegetation are only absent in the case of the Paphos Post Office building, which resulted from the many limitations of the plot together with the decision to face the sea and the public road. Similarly, south facing verandas were not identified in the two buildings at Paphos. The small plots along with the orientation of the public road – as was first considered – also eliminated this feature. Nevertheless, the Paphos District Administration building still incorporates a southeast semi open space, since the south side faces another plot. The features less common, yet still to be found in more than half of the buildings that were investigated, are the "portico", adjustable louvers, central courtyard and the stack ventilation strategies. With regards to stack ventilation, unfortunately in some cases this could not be identified, nor if operable top-windows existed in the building fenestration. The least common bioclimatic features were the ventilated roof, found in two of the seven cases, and the positioning of secondary spaces to the north side of the buildings, a condition only observed in the Government House.

This study found that colonial buildings incorporate both local and imported architectural and bioclimatic elements. The elements to be found also in the local vernacular architecture are high thermal mass, semi-open spaces, cross and stack ventilation, window shaders, utilization of solar gains, courtyards and vegetation [3]. The colonial bioclimatic elements departing from vernacular architecture elements are the closed roofs with wooden ceilings, which became characteristic of urban architecture from this period, as well as the natural ventilation system served by in-wall ducts and the increased number of wide and high windows and glazed doors. This study identified and presented the common bioclimatic features of colonial architecture to be utilized by engineers during the conservation of colonial buildings in Cyprus and other areas of the Mediterranean basin where similar building types exist. Moreover, these features are part of the authenticity of these historical buildings and as such they should be identified, preserved and enhanced as they may achieve lower building energy demand. The colonial buildings have a unique character and they form a significant part of heritage architecture with many aesthetic, historic and environmental values that should be taken into serious consideration during conservation. The preservation of these buildings is very important, with benefits to the society as a whole.

Table 2: Bioclimatic features of building under study.

	Cooling strategies											Heating strategies			Micro-climate			Materials		Daylight		
	South verandas	East or west veranda	Portico	Window shaders	Adjustable louvers	Stack ventilation	Cross ventilation	Closed pitched roof	Ventilated roof	High ceiling	Light colors on walls	South openings	North secondary uses	Materials utilizing thermal sun radiation	Yard with vegetation	Courtyard	Semi-open spaces of massive structure	High thermal mass	Reduced external paving	Increased number of openings	Top window/skylight	Sum
PP	■	■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	19
Sec.	■	■		■		■	■	■		■	■	■		■	■		■	■	■	■		14
KL	■	■		■			■	■		■	■	■		■	■	■	■	■	■	■	■	16
KN	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	20
LLC		■	■	■	■	■	■	■		■	■	■		■	■	■	■	■	■	■	■	18
PPO		■	■	■	■		■	■		■	■			■			■	■	■	■	■	14
PDA	■	■	■	■	■		■	■		■	■	■		■	■		■	■	■	■	■	17
Sum	5	7	4	7	4	4	7	7	2	7	7	6	1	7	6	4	7	7	7	7	6	

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REFERENCES

[1] Philokyprou, M. & Michael, A., Environmental sustainability in the conservation of vernacular architecture. The case of rural and urban traditional settlements in Cyprus. *Int. J. Archit. Heritage*, **15**, pp. 1–23, 2020.

[2] Philokyprou, M., Michael, A., Thravalou, S. & Ioannou, I., Thermal performance assessment of vernacular residential semi-open spaces in Mediterranean climate. *Indoor Built Environ.*, **27**(8), pp. 1050–1068, 2018.

[3] Philokyprou, M., Michael, A., Malaktou, E. & Savvides, A., Environmentally responsive design in Eastern Mediterranean. The case of vernacular architecture in the coastal, lowland and mountainous regions of Cyprus. *Build. Environ.*, **111**, pp. 91–109, 2017.

[4] Ghaffarian Hoseini, A., Berardi, U., Dahlan, N.D. & Ghaffarian Hoseini, A., What can we learn from Malay vernacular houses? *Sustain. Cities Soc.*, **13**, pp. 157–170, 2014.

[5] Fermor-Hesketh, R. et al. (eds), *Architecture of the British Empire*, Weidenfeld and Nicolson: London, 1986.

[6] Georghiou, C., *British Colonial Architecture in Cyprus: The Architecture of the British Colonial Administration, 1878–1960*, En Tipis: Nicosia, 2013.

[7] *A Building with Cypriot Style*, PROINI, 02/03/1935, p. 1.

[8] Schaar, K.W., Given, M. & Theocharous, G., *Under the Clock: Colonial Architecture and History in Cyprus, 1878–1960,* Bank of Cyprus, 1995.
[9] Chang, J.-H. & King, A.D., Towards a genealogy of tropical architecture: Historical fragments of power-knowledge, built environment and climate in the British colonial territories. *Singap. J. Trop. Geogr.*, **32**, pp. 283–300, 2011.
[10] Nguyen, V.T.A., Park, J.H. & Jeon, Y., The spatial and environmental characteristics of Vietnamese vernacular houses in Vietnam's French colonial public buildings. *Open House Int.*, **47**(1), pp. 122–134, 2022.
[11] Michael, A., Demosthenous, D. & Philokyprou, M., Natural ventilation for cooling in Mediterranean climate: A case study in vernacular architecture of Cyprus. *Energy Build.*, **144**, pp. 333–345, 2017.
[12] The National Archives, CO/67/272/2 and CO/67/282/1.
[13] https://allaboutlimassol.com/en/the-historic-building-is-a-reference-point-in-court-square-that-continues-to-keep-the-city-alive.

METHODOLOGICAL APPROACH TO INCORPORATING HAUSA TRADITIONAL ARCHITECTURE IN URBAN DEVELOPMENT: THE CASE OF ABUJA, NIGERIA

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ABSTRACT
The advancement of cities is a major topic for consideration in our societies of today, and the same applies to Abuja, Nigeria, where various contemporary architectural styles have sprung up over the past years. Nevertheless, only slight attention has been given to incorporating traditional architecture into our current urban requirements. The main purpose of this research is to suggest possible ways that we can improve urban development with Hausa traditional architecture. A methodological approach is employed in this paper in order to deeply examine and broaden ways Hausa traditional architecture can achieve this in developing urban spaces within the city of Abuja. Results from this paper proved that Hausa traditional architecture adapts well in urban development when traditional building plans, materials and construction techniques are developed. That is, it is expected that the results should spur professionals such as architects, planners, developers and other government control agencies particularly in Abuja to develop models for infrastructure development. This paper concluded, however, that even with the advancement of building technology and materials, Hausa traditional architecture still stands out or fits well in the urban development. It also proffers ideas on how Hausa traditional architecture can be incorporated into the urban development.
Keywords: incorporate, Hausa, traditional architecture, urban development, Abuja, Nigeria.

1 INTRODUCTION

Found on the southwest of Sahara, Nigeria happens to be one of the most urbanised nations in Africa [1]. The urban infrastructures across Nigeria are under severe strain as a result of the large number of people migrating from rural areas in the quest for better opportunities [2]. In addition, all of this development and fast urbanization did not come without its problems [3]. Having new kinds of development that indicate a loss in the population's traditional form of identity is one of the issues facing urban regions like Abuja, Nigeria. Technology and globalization have merged into one culture, abstracting old traditions [4]. A future generation will lack knowledge of their roots as a result of the disintegration of rich traditional heritage, the replacement of traditional architecture with current and modern-day architecture, and with the replacement of traditional arts and crafts with new designs [5]. As a result, building professionals, notably architects, have not yet made sufficient attempts to incorporate traditional and native design concepts, methods, and crafts into modern practices. The increasing dominance of contemporary technology and concepts will be detrimental to indigenous skills in building design and construction [6]. Despite the fact that it is evident that traditional architecture has recently been frivolously disregarded in Nigeria by architects, designers, and government regulations, less consideration has been given to connecting traditional architecture with current development. Therefore, the goal of this study is to close the existing gap, by evaluating the methodological strategies utilized to incorporate Hausa traditional architecture into Abuja's development in Nigeria. The precise goals of the research are to (1) define the key characteristics of Hausa traditional architecture and (2) choose appropriate methodological techniques for incorporating Hausa traditional architecture into urban development in Abuja, Nigeria. In order to accomplish this, the following research inquiries were posed: what distinguishes Hausa traditional architecture in

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particular? What appropriate methodological techniques should be applied to incorporate Hausa traditional architecture into Abuja's urban districts as they develop?

The study's findings are helpful in educating architects about traditional and cultural building environments that utilise indigenous building innovations and technologies.

2 METHODOLOGY OF RESEARCH

2.1 Locale of investigation

Abuja is situated 840 m (2,760 ft) above sea level at latitude 9.07°N and longitude 7.48°E geographically (Fig. 1). The city is part of the Federal Capital Territory, which is more than twice as large as Lagos state, Nigeria's former capital, and is the continent's most populous nation and sixth-most populated nation globally [7]. The territory's topography is marked by two well-known rock formations: Zuma rock, where FCT originates, and Aso rock, located east of the city [7].

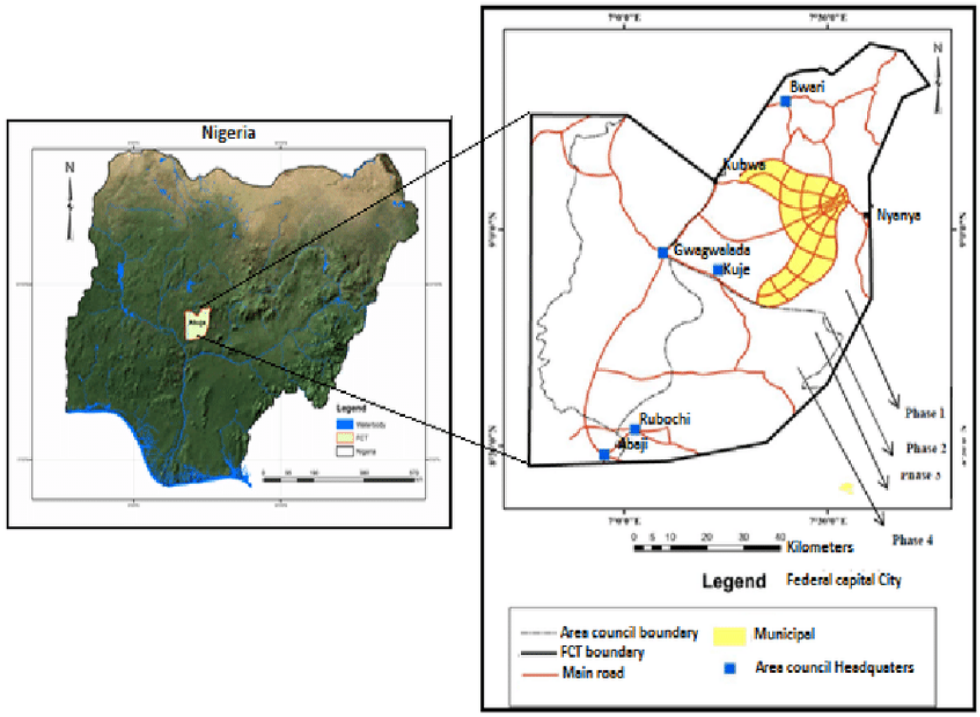

Figure 1: Map of Nigeria, showing the location of Abuja (federal capital territory) [8].

Due to its altitude and tropical position, Abuja has a moderate climate, which differs significantly with the humid climates of Lagos, situated on the Atlantic Ocean's coast at 35 m (11 ft) above sea level. Abuja region has two seasons: rainy season, which lasts from April to October, with rainfall ranging between 305 and 762 mm (12–30 in.) as well as temperatures exceeding 40°C in May, and dry season, which lasts from November to March and comes with dry winds that reduce temperatures to as low as 12°C. Due to abundant

rainfall, fertile soil, and its location within the Guinea Savanna vegetation region, the location is agriculturally productive, with maize and tubers as its principal crops [8].

2.2 Data collection methods

This study used a variety of approaches to collect data, including field surveys, observations, and secondary data from published sources.

3 HAUSA TRADITIONAL ARCHITECTURE

The "Hausas" live in seven centralised medieval fortified municipalities – Gobir, Biram, (Hadeija), Katsina, Kano, Kaduna, and Rano – which are generally referred to as the "Hausa States" (Fig. 2). Islam is the most common religious belief among these territories; it arrived in the 14th century and enhanced the Hausa monarchy and customs that already existed. The British colonial conquerors introduced a new form of governance and their distinctive architectural style in the late 18th century.

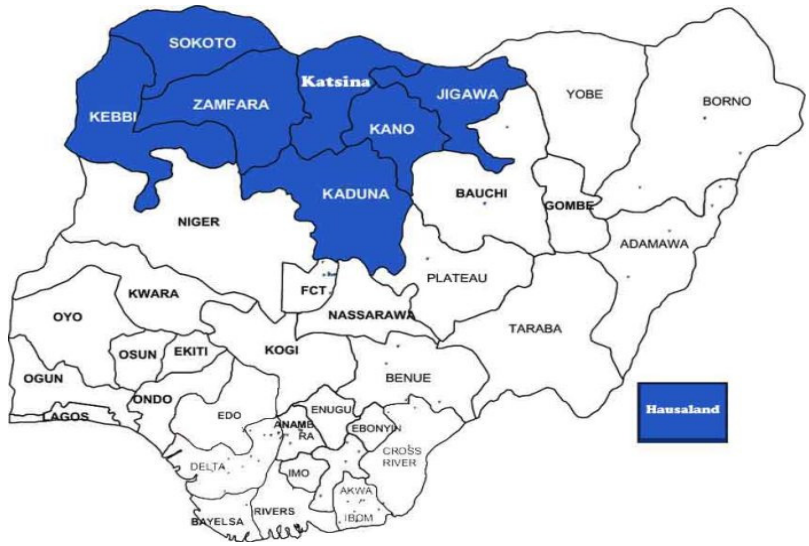

Figure 2: Map of Hausaland [8].

3.1 Functional spaces in Hausa traditional architecture

3.1.1 Hausa compound structure

"A typical Hausa dwelling is theoretically separated into three parts or layouts: 1. inner core (private space), 2. Centre core (semi-private area), and 3. Outer core, (public areas)" [9]. The ward, guest/servant area, and backyard space for animal rearing and waste disposal make up the women's section, which is located in the centre of the compound. The majority of the central core is a courtyard used for domestic and other sociocultural interactions, and also for ventilation and lighting. These ideas first appeared in Egyptian residential architecture in the late (500 CE). As a result, the traditional village layouts of the Hausa people transformed into towns and villages with this kind of typology [10]. The family carries out the majority of their daily domestic tasks as well as other social or ceremonial activities in the compound's

central open courtyard. It's also an area where toddlers may play or crawl peacefully without being disturbed. Meanwhile, one can also interact and dine with other family members and sleep through hot nights or seasons (Fig. 3). In Hausa compounds, there is a clear distinction concerning internal and outside spaces.

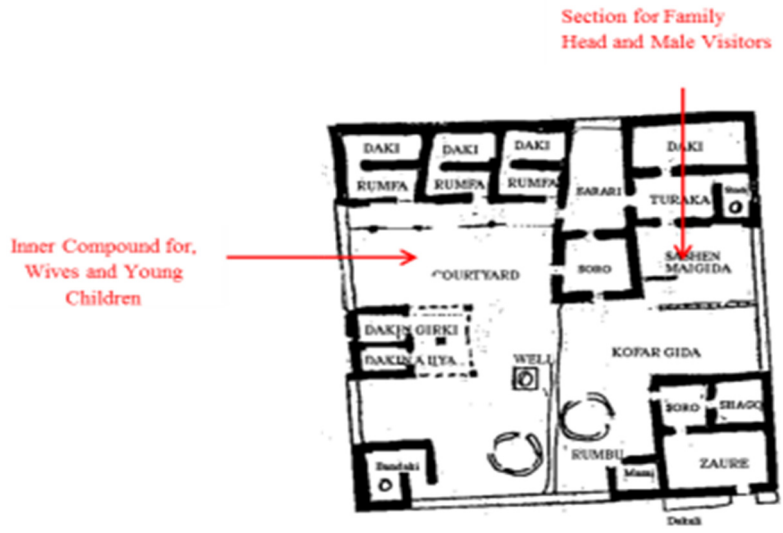

Figure 3: Plan of a Hausa compound [10].

3.1.2 Islamic architectural style

Islamic architectural style is inspired by "PUR-DAH" (women's exclusion) zones such as Haremlik and Selemlik (non-accessible and accessible). The courtyard structure is used for social and domestic undertakings, while dining and kitchen areas are also important but the kitchen is sited faraway in the compound and the dining placed either separately or together in a lounge or open space. All these are the three common integrated spaces that are properly highlighted in other parts of the courtyard. For purposes of privacy, health, and other considerations, the restroom(s) are situated far from or at the end of the compound (Fig. 3). "Zaure's" main function comprises of protection, security, hospitality, privacy, ethnic values, ornamentation, and administration [11]. Furthermore, the availability of a relatively wide space within the community enables congregational gathering to perform social occasions – for example, naming ceremonies, marriage ceremonies, and a play area for kids, among other things. The spacious area is devoted to livestock rearing, small farming, and for future development. The constructed spaces include bedrooms and sitting area, a kitchen, an entry space, restrooms, and storage [12]. The heights of compound walls are raised sufficiently to avoid any external person from observing what is happening within.

Nevertheless, the impact of religion as well as culture is also seen in the zoning system for privacy, including public, semi-public, and private areas – that is, public areas for guests, limited and unlimited areas for visitors and for boys and servants, which are referred to as semi-public, and private areas that are strictly for the household, in which the term "Ba shiga" is implied. These are completely inaccessible areas. The visitor spaces, on the other hand, are accessible. The master's wing remains the quiet zone, while the family area is semi-noisy and the public (guest) area is the noisy zone of the compound [12] (Fig. 4).

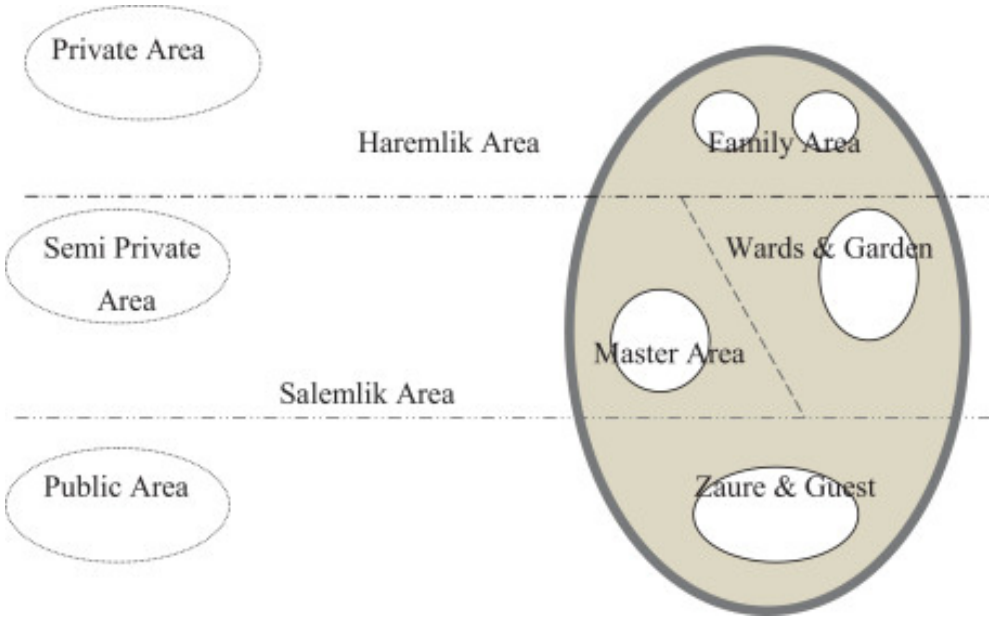

Figure 4: A form of Hausa compound layout [12].

4 HAUSA TRADITIONAL ARCHITECTURAL CHARACTERISTICS

Hausas have a rich architectural legacy that is regarded as the most magnificent of the mediaeval period. Most of their early buildings, including mosques and palaces, were decorated with artistic motifs or vibrant colourful engravings that are designed on the façade. These traditional structures were made in a variety of sizes and designs, having a unique aura because they were made to inspire pleasure and elation. In fact, how a building is constructed and the sheer artistic skill that goes into it both work together to reflect characteristics of people's growth, culture, and history and go a great way toward reflecting the specific surroundings of people's mindsets [13]. Construction uses naturally existing elements like adobe, timber, stone, and thatch that don't require a lot of energy to obtain. Almost all building components, including foundations, walls, columns, slabs, beams, roofs, openings, and rehabilitation processes, require these building materials. In addition to this, other unique qualities, ornamentation, and engravings can be constructed using these building materials. These various components are described below.

4.1 Adobe

Adobe is a plentiful resource in the northern part of Nigeria and indeed the primary traditional material used for the manufacture of bricks and finishes. Because of its excellent thermal characteristics and delayed absorption and release of heat, it keeps building occupants warm at night and cool during the day [14]. The earthen walls are built functionally better than sand-crete block walls and are significantly less expensive, with minimal heat conductivity [15]. These earthen buildings are environmentally sound, remain firm and stable once walls are plastered, and can last for many years if regular care is followed and roof overhangs are appropriately placed [16] (Figs 5 and 6).

Figure 5: Adobe used as a building material in constructing the 15th-century Gidan Rumfa in Kano [14].

Figure 6: Adobe used as building material [10].

4.2 Stone

For structural support and as a moisture barrier, Hausa architecture uses stones in the foundation of its buildings [17]. Stone is utilised in walling in certain northern states, most notably Katsina to symbolise authority. It has been noted that several native authority buildings feature stone walls. When compared to the typical over-site concrete floors, stone foundations offer a less expensive option, particularly as it needs less upkeep and because it guards isolated walls from the outside environment (Figs 7 and 8).

4.3 Engravings and wall décor

Engraving is the process of carving designs onto wall surfaces using different types of grooves (Fig. 9). It has been done from hundreds of years before Christ [18]. Typically, this

Figure 7: Stones used as retaining wall [23].

Figure 8: Perfectly cut flagstone from limestone used for wall caps, pool decks, garden walkways, and patios [23].

is done by expert hand engravers, competent traditional builders, and artisans. The three groups of Hausa traditional architectural decoration – surface design, calligraphy, and ornamental – are well known [19]. Even the colour finishes for these products are made

Figure 9: Engraving works on the façade [14].

entirely from natural ingredients. These engravings endure time's effects to a respectable extent. These colours and decorations are used to reflect the building owner's status quo and symbolise riches.

4.4 Timber

In Hausa traditional structures, walls and pillars are made of solid structural timber. The beams, brackets, and corbels that are used to support flat and domed roofs are made from the trunks of male palm trees (Dalep or Gingiya), which are also referred to as "Azara" beams. These beams are utilised to build frame structures. They are robust, durable, and termite resistance. They are also treated with solutions obtained from trunks to seal the tops of roofs that are usually flat [20].

4.5 Grass and thatch

The thatching process is a practice of building construction that has existed for more than three centuries and has been handed down from generation to generation. Ancient African structures were frequently thatched with grass. These building supplies are made from matted straw from wheat, oats, barley, rice, and other grains. They are used to build walls that are stuccoed using lime or earth [16]. In many underdeveloped nations, thatch is used by traditional builders because it is inexpensive and can be easily obtained from local plants [18].

5 DISCUSSION

Modern construction and Hausa traditional architecture have the inevitability of incorporation at the traditional level. Traditional building that is incorporated with religious beliefs have been sustained over the past years. The methodological systems employed are discussed below.

5.1 Intensive conduct of architectural research works

To determine the culture and lifestyle, as well as the growth patterns of Hausa architectural practice and typologies, extensive literature reviews should be conducted. It is important to conduct research on the usage of organic and sustainable materials that enable buildings to adapt to tropical climates. This would significantly contribute to the creation of practical and long-term developmental urban strategies, particularly in Abuja, Nigeria.

5.2 Observe Hausa traditional principles of design process

As a result of the present tremendous urban development, there is a need for innovation in buildings aesthetics, ideas, and efficiency. The Hausa architectural style has many shortcomings that must be taken into account for urban development objectives. Architecture is a form of poetry that must be built from its roots and conveyed properly in its language rather than being copied after imported models [21]. As previously said, more practical building design activities should be aimed at reconciling traditional and modern planning approaches. For example, re-establishing the idea of triple space will help towards developing and sustaining a healthy society and connecting the city together, encouraging safer neighbourhoods, and creating a vibrant community culture. Its usage of a courtyard, which has effectively linked "the outside environment to the inside", devoid of violating privacy, must be promoted and continued, since the benefits of the conceptual plan is clearly realized in Hausa typical home setups.

5.3 The incorporation of traditional construction materials, building methods, and practices

Isa et al. [17] stated that adobe brick innovations have been used to house one-third of the world's population, with 30% of the world's population living in adobe dwellings, according to the UN [22]. In the past few years, there have been attempts to preserve adobe with additives and compaction for prolonged use in Abuja as well as its surroundings. The Nigerian Building and Road Research Institute (NBRRI) [23], established under the auspices of the Federal Ministry of Science, Technology and Innovation, has produced a number of research discoveries, among which is cement-stabilized adobe blocks (Fig. 10). These are created by adding cement and water to laterite soils. When building brick walls, mortar is used to lay the bricks. It is thermally comfortable and cost-effective for wall building. This shows that by incorporating its building technology, traditional materials have been able to be altered to meet current demands [24].

5.4 Conduct thorough field research and analysis

To determine how well different building materials and technologies relate, a thorough analysis of their qualities, applications, and properties must be conducted. The strength, durability, density, thermal values, water absorption, and moisture content of building materials should all be considered. Additionally, market research should be done to make sure the product is accessible, affordable, and useful. The comparative benefits in terms of performance and affordability should be supported by data acquired with regard to quality, applications, and cost.

Figure 10: A house under construction using NBRRI CEB technology in north-central Nigeria.

6 CONCLUSION

This paper adopts a methodological method of incorporating Hausa traditional architecture into urban development within the city of Abuja, Nigeria. An intensive study has proven that the utilization of improved low-cost traditional building materials such as adobe, stone, wood, and thatch in design and construction is functionally and aesthetically appealing. The utilization of Hausa architectural murals, motifs, decorations, and symbols in contemporary formats can be used aesthetically in streetscapes within the city, thereby giving the urban centres outstanding beautification to attract more visitors.

REFERENCES

[1] Onibokun, A. & Faniran, A., *Urban Research in Nigeria*, IFRANigeria, 2013. DOI: 10.4000/books.ifra.534. p.194.
[2] Pacheco-Torgal, F. & Jalili S., Earth construction: Lessons from the past for future eco-efficient, 2012.
[3] Ajayi, O.O., Oviasogie, F.O., Azuh, D.E. & Duruji, M.M., Urban design and sustainable development: A case of Makoko area of Lagos State, Nigeria. *European Scientific Journal*, **2**, 2014.
[4] Wang, Y., *Globalization Enhances Cultural Identity*, Harbin Engineering University, China, 2007.
[5] Falola, T., A history of Ibadan, 2003. http://en.wikipedia.org/wiki/Ibadan.
[6] Popoola, J.O., Responsive housing: The spatial formation of housing environment in Hausaland, Nigeria and the implications for public housing strategy, 1984. Nottingham UK, 1986.
[7] Abubakar, I.R., Abuja city profile. *Cities*, **41**, pp. 81–91, 2014.
[8] Federal Capital Development Authority (FCDA), The masterplan for Abuja: The new federal capital of Nigeria. *Global Urban Future*, 1979. http:///www.yearofplaneteath.org.

[9] Brunkskill, R.W., Vernacular architectural fourth edition place by Butler/Turner Ltd, UK, Construction. *Constr. Build. Mater*., **29**, pp. 512–519, 2000.
[10] Moughtin, J.C., Settlements and buildings as the physical expression of a culture: A case study in Nigeria. *The International Karakoran Project*, Vol. 1, ed. E.J. Miller, Cambridge University Press: Cambridge, 1984.
[11] Adamu, M., Interpretation of significant and messages in Hausa traditional architecture. Case of the "Zaure" entrance hall. *J. Assoc. Archit. Educ. Niger*., **4**, pp. 10–21, 2005.
[12] Dmochowski, Z.R., *An Introduction to Nigerian Architecture*, Northern Nigeria Ethnographical Ltd.: London, pp: 1–20, 1990.
[13] Chokor Boyowa A., Changing urban housing form and organization in Nigeria. *Lessons*, 2005.
[14] Haruna, I.A., Hausa traditional architecture, 2016. www.ibrahimharuna.com/lectures. Accessed on 17 Mar. 2021.
[15] Oluwagbemiga, P.A. & Modi, S.Z., Development of traditional architecture in Nigeria: A case study of Hausa form. *International Journal of African Society and Traditions*, **1**(1), pp. 61–74, 2014.
[16] Ejiga, O., Paul O. & Cordelia O., Sustainability in traditional African architecture: A springboard for sustainable urban cities. Sustainable Features: Architecture and Urbanism in Global South Kampala, Uganda, 27–30 Jun., 2012.
[17] Isa, I.D., Xue L.S. & Dalibi, G., Vernacular architecture of northern Nigeria in the light of sustainability. *International Conference on Environment and Energy Engineering and Energy Engineering*, **63**, p. 1.10, 2017
[18] AllAfrica, Nigeria: Buildings of Northern Sector. https://allafrica.com/stories/200202200154.html. Accessed on: 10 Oct. 2022.
[19] World's oldest engraving discovered, *Australian Geographic*, 4 Dec., 2014.
[20] Fatty, H., Natural energy and vernacular architecture. *Theories and Manifestoes of Contemporary Architecture*, 2nd ed., eds C. Jencks & K. Kroopf, John Wiley: Sussex, pp. 144–145, 2006.
[21] Adeyemi, E.A., Meaning and relevance in Nigerian traditional architecture: The dialectics of growth and change. Public Lecture Series, 2008. http://eprints.covenantuniversity.edu.ng/1367/1/Prof%20Adeyemi%27s%20Public%20Lecture%2012.pdf.
[22] UN, *World Urbanization Prospects*, 2014 revision. United Nations: New York, 2014.
[23] Orewere, E., Owonubi. A., Go'ar, L.L. & Oguledo, C.A., Enhancing outdoor landscape development through the use of stones in Jos, Plateau State. *Journal of Agriculture and Environmental Sciences*, **9**(2), pp. 32–43, 2020. DOI: 10.15640/jaes.v9n2a5 URL: https://doi.org/10.15640/jaes.v9n2a5.
[24] Denyer, S., *African Traditional Architecture*, Heinemann: London, pp. 164–165, 1978.

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TOWARDS SUSTAINABLE HERITAGE CONSERVATION IN EGYPT: A DETAILED ANALYSIS FOR IDENTIFYING THE VALUES USED IN SELECTING HERITAGE BUILDINGS

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ABSTRACT

Listing heritage buildings in a certain country is the first step towards building conservation and sustainability. Thus, national governments, agencies, or organizations are responsible for deciding whether a building is of special value that should be listed. Different building conservation systems all over the world aim to preserve their heritage by identifying values based on the global principles agreed upon in all charters and treaties. Value concept passed through a long evolution of human thought including historical, artistic, social, political, educational, cultural, and many others. However, such various dimensions of values have become beyond the discussion and analysis of heritage conservation projects. This research seeks to identify and collect all values for selecting heritage buildings to facilitate their registration and management. Therefore, the study focuses on reviewing the existing criteria for listing heritage buildings in five countries: Canada, United States, United Kingdom, Australia, and the European Union. According to the results of the content analysis, by summing up all criteria needed for listing heritage buildings, a detailed analytical study for values and their indicators is conducted to improve and facilitate the listing management system in Egypt. Furthermore, the result shows the values and indicators that need to be added in the assessment criteria of Egyptian national law. This can raise the awareness and significance of various heritage buildings preventing their neglect and demolition.

Keywords: conservation, heritage buildings, cultural values, documentation, listing, criteria, sustainable heritage.

1 INTRODUCTION

The evaluation of heritage criteria is based on the building's values, which include the degree of significance, condition, integrity, and authenticity. The importance of heritage buildings is figured out by a range of values that reflect the nature of each structure. "Heritage impact assessment" is used to identify the values and indicators in heritage buildings to determine the appropriate restoration process in relevance to the assessment results [1]. Consequently, *Criteria* are tools or methods for identifying, evaluating, analysing, measuring, and determining the significance of heritage buildings or sites. They contribute to the integrity and discipline of the evaluation process. Criteria bound a wide range of indicators, which form a framework for determining different *significance values*. As a result, historical buildings and sites must reflect a range of significant values to show its uniqueness, with a set of characteristics that indicate its historical importance. However, different factors must be analysed and evaluated to decide whether a building is worthy of inclusion or not [1]. A comparison was drawn between the ancient maps and the new satellite image to determine the locations of the listed buildings and their context and address their present value to the area and the list. The list of Alexandria's historical buildings and sites does not include any information on how to preserve their sustainability. Therefore, many heritage and historical buildings have been affected by the factors of environment erosion and are not well documented, which led to the disappearance or demolition of their heritage values [2]. The

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aim of this research is to generate a systematic detailed analysis for the evaluation criteria, as to fully define everything related to the building that makes it eligible for registration. This could be achieved by studying and analysing these values and their indicators to emphasise the importance of the historic buildings and sites in line with international treaties and national laws. This study recommends a set of detailed values and indicators used in selecting heritage buildings worldwide to enhance the listing process in Egypt, due to the lack in the heritage management listing system. In addition, it aims at finding solutions to protect heritage buildings in Egypt and sustain the quality of culture heritage through reviewing different international rating systems. Finally, the paper objectives are to enhance local values and indicators used in selecting heritage buildings in Egypt. This could ensure the accomplishment of management practices and methods to remain adequate in protecting the cultural heritage buildings under safeguard and provide an extensive review of research on Sustainability of Heritage Buildings (SHBs)

2 DEFINITIONS

Heritage documentation is a basic process that can influence and facilitate any essential actions to protect historical buildings for future generations or to enhance their effectiveness and performance. Consequently, documentation is critical to a building's sustainable and long-term survival. Besides, heritage building documentation helps in forming better awareness of the building's history, including its past sociocultural context, building technologies and used materials. The systematic recording and archiving of intangible and tangible features of historical buildings and environments referred to as heritage documentation. It aims to provide correct and precise information that allows appropriate conservation, management, and maintenance to sustain its survival. Documentation is the first step in heritage building evaluation, conservation, adaptation, renovations, and maintenance. It has the authority to include both quantitative and qualitative values [1].

Heritage conservation, in its many forms, types and historical events, is based on its ascribed values. The capability to appreciate these values is influenced by the extent to which data sources concerning these values are recognized as reliable or accurate. Understanding and analysis of data concerning the original and following heritage features with their significance is a critical prerequisite for analysing all elements of authenticity.

Listing of heritage buildings, sites or areas is a type of documentation process which has cultural or historical symbolic importance that has been selected and organized by national authorities, institutions, and private organizations. Listing heritage contributes, guides, and aids in promoting knowledge and appreciation for the significance of such buildings, sites, or areas. In addition, it provides awareness of inherited values to the individuals, society, and stakeholders in the community, thus enhances community members' enthusiasm and gives a sense of place. Furthermore, it can participate and contribute to the development of tourism [3].

Sustainable heritage is the main goal for any conservation management program. The Brundtland Commission of the United Nations defines sustainability as "the development that meets the current needs without compromising the needs of future generations' potential". In general, any sustainable development that fulfils description will support the conservation of cultural heritage. The conservation approach of heritage-building is the ultimate of sustainable development as it is based on a desire to protect a building so that it can be valued by current and future generations with more socio-economic benefits. In terms of social cohesiveness and identity, heritage buildings contribute to create a feeling of place, educate, and promote social cohesiveness. Therefore, they create and maintain "social value". In terms of economics, heritage buildings can improve a community's economy by

encouraging heritage tourism. In addition, they help to show a "feeling of place" that attracts visitors. Furthermore, there are social and operational benefits for heritage building occupants relating to "feeling better" about inhabiting and helping to maintain something of communal importance. The concept of "sustainable tourism" was mentioned in literature in the 1980s. The development of the concept of "sustainable development" protecting, preserving, and promoting natural, historic, cultural, social, and aesthetic values, which are the source of tourism, is the concern of sustainable tourism [4].

Authenticity in tools or materials is a major factor for validity in design and craftsmanship, which defines the historic resource with value in context. Historic resources are affected by natural development and human use, and these changes are part of the historical division. "The presence of authenticity in a heritage building and its context will be the basis for the measurement of applicable cultural values". In the 1994 Nara Conference, Jokilehto stated that "identifying of variables for the standard of relevant authenticity will also be dependent on these values". Considering today's society, its character, and the problems it faces in relation to its own identity and authenticity, it will be necessary to maintain the authenticity of existing heritage resources from the past [5]. Heritage buildings will form a reference for future memory and will therefore need to be conserved with due respect for relevant issues. A proper procedure is necessary for dynamic conservation management of the physical environment and the approaches to authentic cultural traditions which will require assistance with general planning and administration to maintain their authentic creativeness.

3 METHODOLOGY

The paper seeks to identify and collect all values and indicators that are used for selecting heritage buildings to facilitate its registration, and therefore, its management. Therefore, the study focuses on generating a detailed analysis for listing and evaluating listing heritage buildings criteria in different countries with different cultural policies that are planned and implemented in various Member States or National Federals and determining their cultural policy and methods according to their own conception of culture, socio-economic system, political belief, and technical development to improve and facilitate the listing management system in Egypt.

4 LITERATURE REVIEW

The literature review is presented in two parts. The first part shows the international charters and treaties standards for listing heritage buildings, and the second part reviews the different policies and standards guidelines of the five different countries as well as Egypt.

4.1 Declaration and standards of listing buildings according to international charters and treaties

In 1954, The Hague convention in the event of armed conflict adopted by international conference by UNESCO conducted the international list for protecting cultural heritage under any condition. In Chapter II, procedures and framework in listing the heritage buildings are promoted to ensure high degree of protection to heritage resources to achieve certain criteria and conditions [6].

In 1964, The Venice Charter for Conservation and Restoration of Monuments and Sites declared that "The purpose of listing is to provide a degree of recognition and protection for buildings of cultural and historic significance" [7].

In 1966, according to National Historic Preservation Act, the National Register of Historic Places (NRHP) is an official list of places, sites, buildings, constructions, and artworks by

the United States Federal Authority that has considered great conservation building to their historic value. The property must contribute to the major theme of American history which is classified into four categories [8]: Related to historical events. Entity is related to historical figures or famous people in the past United States. Architecture style is concerned with the building's identifying architectural and construction qualities and features, such as having considerable artistic value or uniqueness. Information value, when the building has presented or may be intended to provide a good source of information of ancient history or past.

In 1972, the world heritage convention declared the strategic guidelines and standards for listing the heritage cultural and natural resources, in support by UNESCO Institute. The Convention's secretariat founded three technical responsible committees: IUCN, ICOMOS, and ICCROM. In 1977, the committees established the operational guidelines for selecting heritage buildings. For cultural property, the following criteria must be met: Exceptional significance in terms of impact on successive developments, uniqueness, important example of building type, sensitivity of traditional forms, and historical significance value.

The Committee also created a list of World Heritage in Danger that include buildings threated by disappearance caused by rapid deterioration, large-scale public or private projects, or rapid urban development projects, destruction caused by modifications and its significant changes, natural disasters like fires, earthquakes, floods, and tidal waves [9].

In 1979 and 1999, The Burra Charter (Australia's ICOMOS Charter for Buildings of Cultural Significance, Site, area, landscape, buildings, and other work) is declared. This charter's goal is to define cultural importance referring to the aesthetic, historic, scientific, social, or spiritual value of a location for past, present, or future generations. Cultural significances are represented in the location, fabric, function, relationships, meanings, and related entities. Burra Charter included three additional terms in 1979: site, location, building or group of buildings with relevant elements and surroundings. Cultural value refers to aesthetic, historic, scientific, or social worth. Fabric refers to all the physical form of the location [10]. The declaration of Nizhny Tagil Charter for The Industrial Heritage created by TICCIH has a social value which gives a significant feeling of identity, has an aesthetic and rarity value due to its artistry and quality in architecture style, form, design, and its scientific meaning, and significance value in technology, construction, and structure. Consequently, these values are embedded in the site's fabric, characteristics, equipment, and context. Landscape should be analysed and well-documented [11].

In 1993, The Director of the UNESCO Local Project proposed a method used in monitoring program for listing the cultural heritage, which emphasises and recognizes how the strategies is constantly revised in discussion with those involved in the monitoring system and based on the past recommendations from the advisory parties [12]. The submission group for listing the heritage building must be included as shown in Fig. 1.

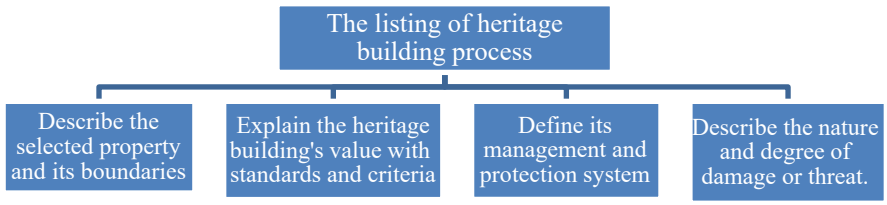

Figure 1: The listing the heritage building process [13].

In 1994, according to Nara document, evaluating all elements of authenticity requires knowledge and understanding of various sources of information in relation to the original and later qualities of the cultural heritage and their meaning. The values linked to the cultural heritage are the basis for preserving cultural heritage in all its aspects and historical period. The level to which sources of information about these values can be taken as reliable or accurate influences facilitates understanding heritage buildings [5]. When evaluating or dealing with World Heritage sites, two classifications should be considered: cultural values and socio-economic values. First, cultural values are divided into three categories: identity value, which is dependent on recognition, artistic and technical value, which is based on research, and rarity that is based on statistics. Secondly, socio-economic values which are linked to economic, functional, educational, social, and political values [14].

4.2 Principles of selecting heritage buildings in different listing regulations

In this part, the research focuses on national heritage lists of five different countries to understand how value-based criteria are used to list heritage buildings. These countries were chosen based on their history of longstanding heritage of preserving their cultural heritage. Therefore, the assessment criteria used for selecting or listing heritage buildings in different countries is analysed to show the selection process according to their own conception of culture, their socio-economic system, and technical development.

4.2.1 European Union

In 1985, the Granada Protection Act of Europe's Architectural Heritage introduced the principles of European coordination and collaboration in the field of architectural conservation in 25 member States. Half of the world heritage buildings are in Europe, with most of them in the European Union. Italy is top, followed by France, Germany, and Spain, all of which are ranked second. The 2005 Framework Convention on the Social Value of Cultural Heritage (the Faro Convention) emphasized the social and economic benefits of cultural heritage preservation as a requirement for achieving sustainable development [15].

According to the Culture and Heritage Law and the general evaluating cultural heritage to develop a legal status for protecting cultural heritage, the criteria for heritage value, the principles and conditions for the evaluation process and related documentation, all are defined in the guidelines and regulations for selecting heritage buildings. The main criteria of heritage significance fall into three categories: associative significance, vital significance, and contextual significance. The buildings and sites must achieve the following specific goals [16]: emphasizing their importance to Europe. Artistic, cultural, and historical educational value for raising awareness among Europeans, especially among young people. Promoting the economic and sustainable growth of regions, particularly through cultural tourism, to increase their attraction

4.2.2 Canada

In 1982, The FHBRO controls set of procedures that are explained in the policy, such as the evaluation of the historical significance of federal historic buildings, the review of proposed alterations to federally mandated historical buildings and gives conservation guidance. FHBRO development is based on the responsibilities related to cultural heritage under the Treasury Board Policy on Monitoring of Real Property. The possibility of providing a sustainable, new life for the historic location is figured out by an evaluation of historical value and physical suitability with the historic place. These four criteria, "Aesthetic Design", "Functional Design", "Craftsmanship", and "Designer", are aimed to evaluate the

architectural building's value, both in terms of design and implementation. In applying these criteria, the current state of the building must be considered, with the consideration that inappropriate changes or demolished fabric could damage or affect the building's architectural value. The Standards and Guidelines have grown into a crucial tool for heritage conservation across Canada since their first publication in 2003. A set of criteria is defined as a group of values, and buildings are measured in the simplest form of architectural evaluation system [17].

4.2.3 Australia

The National Heritage List is managed by the Ministry for the Environment, Heritage, and the Arts, by the Environment Protection and Biodiversity Act 1999 (the EPBC Act). The Minister can only make this decision under the EPBC Act after receiving a policy from the Australian Heritage Council and having a stringent legislative evaluation process to determine whether places on the Finalized Prioritized Evaluation Register for acceptance in the National Register of historic places fulfil the criteria, and to determine whether a building achieves the criteria, where the procedure must analyse and evaluate relevant details. Criteria are a set of principles, qualities, and classifications that will be used to decide whether a building has a heritage value. A heritage list usually has multiple criteria, and some of them must be fulfilled to be evaluated for listing. During the assessment process, the eligibility guidelines are taken into consideration [18]:

- To emphasize the values of the criteria and create checklists for evaluators to determine whether a building has interest and high cultural significance. The significance indicators are not an extensive list of values.
- Figure out the authenticity of the heritage value to verify its originality

The criterion is to show important aspects of architectural design styles and its aesthetic significant, typologies, and other elements that are important to Australia and its way of life. Cultural heritage must be included as an important kind within each grouping's general typology; thus, not every subsection of culture is acceptable under this criterion. The criteria are to show outstanding exceptional examples. A one criteria relation change may result in other various criteria. This could happen if it is determined that it is a location or district linked to a significant or connected to Australia's natural or cultural history. Therefore, associative value is a connection between a location and the history or pattern of Australia's natural or cultural history. Cultural values include the aesthetic, historic, scientific, and social values that occur across the spectrum of the heritage buildings.

4.2.4 The United States of America

According to the Historic Sites Act of 1935 (HSA) legislation, the Federal Role in Historic Preservation of America (US Federal Government) indicates that when a local authority receives an application affecting a historic building or area, it becomes necessary to ensure that appropriate information is available to make an informed decision on the proposal's impact. Location or sites, design, materials, workmanship, and association possess a high level of significance in the American history. Buildings of historical figures, sites owned by religious institutions or used for religious purposes, buildings that have been relocated from their original positions, restored historic buildings, properties that are symbolic in character, and buildings that have achieved significance within the last 50 can be listed according to its historical significance value [19].

4.2.5 The United Kingdom (London)

The National Planning Policies Framework has a government planning policy (NPPF) that provides additional protection for listed buildings through the procedures of Listed Building Consent (LBC) and planning authorization (Listed Buildings and Conservation Areas) Act 1990. England has an incredible selection of historical buildings, some of which are world-famous national landmarks. They range from grand cathedrals and palaces to smaller but equally remarkable buildings spread around the country. They form an important part of the historic landscape that surrounds them and enriches the lives of current and future generations. Buildings that meet certain listing requirements, such as having a special interest and values, are given this classification. Some criteria and principles for listing buildings are set in the guidance and selection criteria on the English heritage charter [20].

4.2.6 Egypt

According to National Organization for Urban Harmony, the Egyptian cultural heritage sites include a wide range of types that limit prehistoric to modern times. They must be defined carefully to determine the extent of their importance. For example, there are important historic buildings, sites, and districts in Egypt which do not have accurate or proper evidence that indicates their importance. However, they are known only through writings or oral tradition [21]. According to Law No.117 for 1983: Buildings classified as "historic" if they can be attributed to one of Egypt's essential cultural influences: Greek, Christian, Islamic, or Ancient Egyptian. Law No. 144 of 2006 sets out the standards and specifications for protected buildings; namely, they must hold historical significance such as an association with national events, or an influential historical figure, or hold the architectural or artistic value of art, or buildings that are considered as a popular tourist spot. Law No. 144 of 2006: By contrast, "heritage" classification is much more confusing, and there is no state institution that is explicitly responsible for the official classification or protection of heritage buildings. However, heritage buildings can be identified or recognized by their historical significance that meets the assessment criteria values compared to any historical buildings according to Law No. 144 as shown in Table 1 [21].

5 TOWARDS REACHING A VALUE-BASED CRITERIA CHECKLIST FOR EVALUATING HERITAGE BUILDINGS IN EGYPT

The concept of *Value* emerged from a lengthy line of human thought that included historical, aesthetic, social, political, educational, and cultural considerations, among many others. However, such a wide range of values has moved outside the scope of discussion and analysis in projects involving modern heritage structures. *Criteria* are a set of principles, qualities, and classifications that will be used to determine whether a building has a heritage value [1]. A heritage list usually has multiple criteria, and some or all of them must be fulfilled to be evaluated for listing. The criterion is to show important aspects of architectural design styles, its aesthetic significance, typologies, and other elements that are important to the country and the way of life of its inhabitants. In the criterion, the term "culture" is used in a broad meaning. The criteria are to show outstanding exceptional examples. In the assessment criteria for selecting heritage buildings, there is a set of value indicators as shown in Table 1 referred to Law No. 144 of 2006 for registration heritage buildings in Egypt. From the previous study, it is discovered that some indicators are present in all the previous countries. Therefore, a statistical analysis is done as a conclusion as shown in Table 1 and Figs 2 and 3.

Table 1: The detailed comparative analysis for values and indicators used in assessment criteria for selecting heritage buildings between the five previous discussed countries and Egypt.

Values	No.	Indicators	Canada	USA	UK	Australia	EU	Egypt
Architecture	1	Significant building style	✓	✓		✓	✓	✓
	2	Building age	✓	✓	✓			✓
	3	Related to an important artist or architect	✓					✓
	4	Architectural design of the building	✓	✓	✓	✓	✓	
	5	Workmanship	✓	✓	✓		✓	
	6	Significant plan forms			✓		✓	
	7	Significant building form		✓		✓		
	8	Relation between internal and external spaces	✓			✓		
	9	It represents an important period in the history of art and architecture						✓
Historical	10	Related to important person	✓	✓	✓	✓	✓	✓
	11	Related to important event	✓	✓	✓	✓	✓	✓
	12	Related to national historical areas	✓	✓			✓	✓
	13	Important aspect or impact on nation's economic history			✓	✓		
	14	Important aspect or impact on national socio-cultural history			✓	✓		✓
	15	Important aspect or related to region/local/national history	✓	✓	✓	✓	✓	
	16	Important aspect or impact on political history			✓			
	17	The building developing significance over the last 50 years (national, state and community)		✓				
	18	Educational value of the heritage building to improve understanding of previous lifestyles or activities		✓			✓	
	19	Related to historical themes or activities	✓			✓	✓	

Table 1: Continued.

Values	No.	Indicators	Canada	USA	UK	Australia	EU	Egypt
Environmental	20	The importance of location of the building within the context	✓	✓		✓	✓	
	21	Landmark in the neighbourhood	✓	✓		✓	✓	✓
	22	Impact on area's pattern development	✓	✓				
	23	Compatibility of the building with the context and public service	✓	✓				
	24	Presents a significant intervention process, which made a unique impact on the building		✓				
	25	Historical relation between the building and its associated landscape	✓		✓		✓	✓
Integrity	26	The building sustains its significant features or its construction condition	✓				✓	
	27	Presents a construction modifications and alterations in different phases of building's history	✓				✓	
Aesthetic	28	Visual aesthetic quality in the context of architectural building type	✓	✓	✓	✓		
	29	Design quality of creative artistic details	✓	✓			✓	✓
	30	The significant proportion and scale of the building	✓		✓			
	31	Presents high aesthetic value that reflects cultural identity		✓		✓		
	32	Presents an aesthetic techniques or materials in building's construction				✓	✓	
	33	Aesthetic decorations and ornaments of the building		✓	✓	✓	✓	
	34	External visual aesthetic quality	✓		✓		✓	
Functional	35	Significant example of building's functional types	✓			✓	✓	✓
	36	The building provides potential economic and social advantages and high expressive potential	✓					
	37	The continuity uses value of the building (sustain its use)	✓	✓		✓		
	38	Presents a building's significant phase in the growth or development of the community or reflects a turning point in the community's history (national, locally, and regionally)	✓			✓		

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Table 1: Continued.

Values	No.	Indicators	Canada	USA	UK	Australia	EU	Egypt
Religious	39	Reflects a historical architectural features or artistic uniqueness of a religious building within a certain period		✓				
	40	Spiritual significance value to community		✓		✓	✓	
	41	The historical significance of the religious building		✓			✓	
Rarity	42	Presents an artistic masterpiece of workmanship in a certain region within certain period	✓	✓	✓			
	43	Uniqueness in its characteristic integration				✓		
	44	Rarity quality in its survival type			✓		✓	
Social	45	The quality degree of previous interventions on the building		✓			✓	
	46	Reflects a specific regional and local building's traditions, belief, and lifestyles			✓	✓	✓	✓
	47	Reflect specific significant traditions of community (socially and culturally)		✓		✓	✓	
	48	Reflects significant contribution to community's or district's historical identity (locally or nationally)	✓			✓	✓	
Technological authenticity	49	Reflects building material innovation	✓		✓			
	50	The building related to architectural group that uses unique building materials that express the nature of the place and adapts to the climatic conditions						✓
	51	Reflects technological engineering technique		✓	✓			
	52	authenticity in technological tools					✓	
	53	Authenticity of historical engineering-built techniques					✓	
	54	The use of a material or method of construction that shaped the historic identity of an area		✓				✓
	55	Reflects technical development or inventiveness			✓			
	56	Unique method of construction techniques in engineering history	✓	✓				✓
	57	Sustain its original materials and design elements					✓	

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Table 1: Continued.

Values	No.	Indicators	Canada	USA	UK	Australia	EU	Egypt
Extent value	58	The degree of surviving components of the original phases of the building					✓	
	59	Extent use to the authentic techniques or tools					✓	
	60	Extent use of performance traditions					✓	
Continuity	61	A part of a group or collection of buildings which together have unity as: history, age, appearance, use, construction, style, scale, materials			✓			✓
	62	Reflects historical or cultural continuity history					✓	

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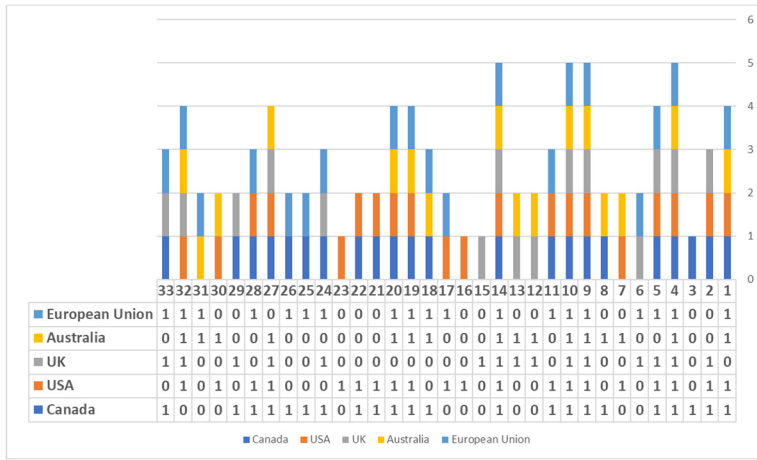
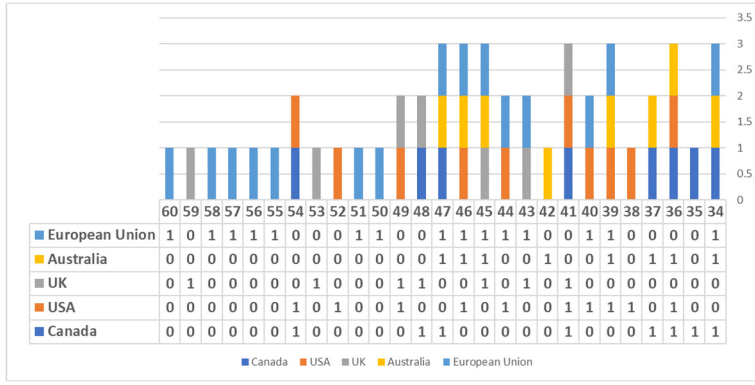
6 RESULTS

As shown in Table 1, the detailed analysis for listing heritage buildings criteria in different countries with different cultural policies that planned and implemented in various Member States or national federal, to sum-up all values and indicators to reach a full understanding of how buildings are selected for listing. Then, this analysis put on a statistical program to show the highest and lowest importance of each indicator as shown in Figs 2 and 3, also proved that each historical building has a value with an indicator that measure its significance. Therefore, the highest common-used indicators considered as the most important indicators that should be proposed and added in the Egyptian evaluating criteria, to raise the significant value of the heritage building, for developing well-balanced management and development strategies to highlight the benefits and potential of heritage buildings for its sustainability. Then, this addition could help in categorize the heritage buildings according to their



	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
European Union	1	1	1	0	0	1	0	1	1	1	0	0	0	1	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0	0	1
Australia	0	1	1	1	0	0	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	1	1	1	1	0	0	1	0	0	1
UK	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	0	0	1	1	1	0	1	0
USA	0	1	0	1	0	1	1	0	0	0	1	1	1	1	1	0	1	1	0	1	0	0	1	1	1	0	1	0	1	1	0	1	1
Canada	1	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1	0	0	1	1	1	1	0	0	1	1	1	1	1

Figure 2: The statistics shows the common and different values and indicators in each country.



	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34
European Union	1	0	1	1	1	1	0	0	0	1	1	0	0	1	1	1	1	1	0	0	1	1	0	0	0	0	1
Australia	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	1	1	0	1
UK	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0
USA	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	1	0	0	1	1	1	1	0	1	0	0
Canada	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	1	1

Figure 3: The statistics shows the common and different values and indicators in each country.

importance from highest value to the lowest value (A) then (B), (C) and (D). Also, could help in creating a viable and applicable methodology to build a detailed point-based checklist for selecting heritage buildings in Egypt.

7 CONCLUSION AND RECOMMENDATION

In this paper, a historical recognition to evolution of world heritage buildings listing systems is presented. Furthermore, the previous study stated a different listing system in five countries. The paper conducts a detailed analysis between listing systems according to the stated countries and Egypt. As a result, Table 2 is deduced.

Table 2: The matrix of comparative analysis between the five national countries from the previous studies and Egypt.

Values		**Canada**	**USA**	**UK**	**Australia**	**EU**	**Egypt**
1	Architecture	✓	✓	✓	✓		✓
2	Historical	✓	✓	✓	✓	✓	✓
3	Environmental	✓	✓		✓	✓	✓
4	Integrity	✓				✓	
5	Aesthetic	✓	✓	✓	✓	✓	
6	Functional	✓	✓		✓		
7	Religious		✓				
8	Rarity	✓		✓	✓		✓
9	Social	✓	✓	✓		✓	✓
10	Scientific	✓	✓	✓	✓	✓	✓
11	continuity			✓		✓	
12	Completeness extent					✓	
	Total	9	8	7	7	8	6

As shown in Table 2, the idea of presenting this table is to analyse all available values and indicators to reach a full understanding of how buildings are selected for listing. The table shows the present and absence of some common values needed to be highlighted in the assessment criteria to raise the significant value of the heritage buildings. This study will be used to enhance the heritage building listing and management in Egypt and facilitate the assessment process in terms of accurate and reliable data. Based on the obtained data analysis, there is a set of important values and indicators that must obtained in the national assessment process to raise the educational awareness of the heritage buildings and their significance values. National authorities should be concerned of creating a reliable and accurate checklist used in heritage buildings evaluation process, as shown, and recommended in Fig. 1. Moreover, the detailed checklist can help in creating a "heritage buildings assessment impact" to sustain and preserve their conditions. Correspondingly, the study recommends adding buildings' types and typologies into the assessment criteria in the national Egyptian law, as it is an essential aspect in evaluating any heritage buildings.

REFERENCES

[1] Feilden, B., *Conservation of Historic Buildings*, 3rd ed., Routledge, 2003.

[2] Nassar, D.M., Heritage conservation management in Egypt: The balance between heritage conservation and real-estate development in Alexandria. *Environment-Behaviour Proceedings Journal*, **1**(4), pp. 95-108, 2016. DOI: 10.21834/e-bpj.v1i4.132.
[3] The Global Development Research Center, Urban heritage and conservation, 2020. https://www.gdrc.org/heritage/index.html.
[4] Embaby, E.M., Sustainability and heritage buildings. *International Journal of Engineering Research and Technology (IJERT)*, **9**, 2018.
[5] ICOMOS, *The Nara Document on Authenticity,* ICOMOS: Japan, 1994.
[6] UNESCO, *The 1954 Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict and its Two (1954 and 1999) Protocols,* UNESCO, 1954.
[7] ICOMOS, The Venice Charter. *2nd International Congress of Architects and Technicians of Historic Monuments*, ICOMOS: Venice, p. 4, 1964.
[8] *The National Historic Preservation Act.* National Park Service: USA, 1966.
[9] UNESCO, *Operational Guidelines for the World Heritage Committee,* UNESCO: Paris, 1977.
[10] ICOMOS, *The Burra Charter,* ICOMOS International Council on Monuments and Sites: Australia, 1999.
[11] The International Committee for the Conservation of the Industrial Heritage, *The Nizhny Tagil Charter For The Industrial Heritage, July 2003*. https://ticcih.org/about/charter/.
[12] ICOMOS, *The World Heritage Convention,* ICOMOS Tourism Handbook for World Heritage Site Managers, 1993.
[13] ICOMOS, International Cultural Tourism Charter Managing Tourism at Places of Heritage Significance. *ICOMOS at the 12th General Assembly*, ICOMOS: Mexico, p. 6, 1999.
[14] UNESCO, *Operational Guidelines for the Implementation of the World Heritage Convention.* UNESCO World Heritage Centre: Paris, 2021.
[15] Pasikowska, M., *Cultural Heritage in EU Policies,* European Parliament, 2018.
[16] European Union, Decision No 1194/2011/EU of the European Parliament and of the Council, *Official Journal of the European Union*, 2011. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011D1194.
[17] Canada's Historic Places, *The Standards and Guidelines for the Conservation of Historic Places in Canada*, 2010.
[18] Australian Government, Department of Climate Change, Energy, the Environment and Water, *Guidelines for the Assessment of Places for the National Heritage List,* 2009. www.environment.gov.au/heritage/ahc/publications.
[19] National Park Service, *Guidelines,* 2020. https://www.nps.gov/hdp/standards/haerguidelines.htm.
[20] Department for Digital Culture, Media and Sport, *Principles of Selection for Listed Buildings,* 2018. https://www.gov.uk/government/organisations/department-for-digital-culture-media-sport.
[21] National Organization for Urban Harmony, *The Principles and Standards for Cultural Management for Outstanding Value of Heritage Buildings and Areas,* Egypt, 2010.

SECTION 11
URBAN AND RURAL AREAS

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FUTURE OF DWELLING: INDOOR PLANTS AND PRODUCE

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ABSTRACT

Our agricultural system has a gigantic task ahead, by 2050 it will need to increase food production by about 70% in order to meet the needs of a global population of 9.7 billion people, 68% of whom are projected to live in urban areas. Presently, 38% of the planet's unfrozen land is used for growing food, using 70% of our water consumption. The agricultural system needs to become more efficient starting by using new technologies to increases productivity. Indoor farming has the potential to present solutions that can help mitigate this problem at both the urban and single dwelling levels. The future of food production starts at home by bringing plants indoors. Interest in greenifying our interiors is not new. As humanity moved from nomadic hunter-gatherers (in the Neolithic) to becoming urban dwellers, plant domestication was one of the main factors behind their settling down. Across cultures all over the world and for generations, humans have brought plants into their homes. Before we called them houseplants, scented and flowering plants were taken indoors so that their fragrance and blooms could be enjoyed, while also masking unwanted smells inside the house. Well known as stress busters, mood enhancers and incorrectly as air purifiers, it's easy to see why houseplants are having a revival. The present trend has been attributed to eco-friendly, health-conscious millennials who want to bring the great outdoors into their inner-city apartments and nurture something alive in an increasingly virtual world, but it could go further than that. What if indoor houseplants could also feed us? The future of dwelling relies on making home grown produce an inherent aspect of the interior environment, using smart gardening, self-watering garden systems, hydroponic kitchen appliances and other emerging technologies to do so. This paper will focus on the future of indoor plants and their sustainable potential in helping mitigate the climate crisis, as they are integrated in an interior environment to help define the future of dwelling.

Keywords: indoor farming, greenifying, plants, hydroponics, sustainable potential.

1 INTRODUCTION

Humans and plants have shared a coevolution that has been central to our well-being. Plants are not only an important source of food and medicine but also inherently present in our culture, legends, folklore, and religions. Their domestication for agriculture presented a major change in human history, allowing society to develop while our settlements increased in complexity and size. Today, modern urban centres rely on the stable and reliable production and distribution of plant-based food to subsist. In globalized society this means produce needs to travel from far away to make it to our plate. This food carries with it a huge carbon footprint (food miles) that takes away any benefits it might have gained through sustainable farming techniques. To counter this problem, the local food movement, with the goal of consuming food produced and grown in its nearby geographical area, has been gaining traction as a way of eating fresh and nutritional foods while reducing one's environmental impact and cutting food cost. Agricultural areas around cities are being complemented by urban farms, in rooftops, residual empty lots, community gardens and vertical hydroponic farms. This last one, with the potential to bring farming indoors into the house, allowing it to produce a percentage of its tenant's plant intake. Indoor plants contribute to our mental well-being but what if they could also be set to provide nourishment. As we look into the future of dwelling, houses will need to give back by recycling and producing water, creating energy from the sun or wind, deal with waste management through

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composting and produce a percentage of their own food. Hydroponics have already started to make their presence known in kitchen appliances, facilitating the agricultural process by making it home friendly. The domestication of plants has arrived indoors in a sustainable, adaptable, and efficient way. Ahead, we will look into the history of the human–plant relationship, their benefits as we bring plants indoor and the future of our relationship to plants in the home. Our motivation may have changed, but it seems that having greenery and flowers in our homes is just as important for us today as it ever was.

2 THE CHALLENGES OF FUTURE-PROOFING OUR FOOD SUPPLY

Humanity is now up against multiple demanding issues that are forcing dramatic change to our global lifestyles: climate change, infectious diseases, increasing urbanization, and the depletion of our natural resources. All of them adding uncertainty to our capacity to feed the planet's inhabitants. With a global population expected to reach 9.7 billion people by 2050 [1], it is expected that food production will need to increase by 60% to 70% [2]. To achieve this under our present system would require 593 million additional hectares of agricultural land. If this amount of land was actually used for this purpose, the climatic implications would be catastrophic. A sustainable plan would have to find solutions that function withing the agricultural land already in use. Taking into account that the population growth will not be evenly balanced around the world. According to the United Nations, India, Nigeria, Pakistan, the Democratic Republic of the Congo, Ethiopia, Tanzania, Indonesia, Egypt, and the United States will be responsible for half of the population growth. Placing economic pressure on their poorest citizens and with that their access to food. But we have to understand that producing the amount of food needed does not guarantee that it will be distributed equitably ending global hunger. Because the vast majority of the population growth by 2050 will take place in urban areas, urban solutions are needed. While the governments of the world will attack the food shortage in multiple ways, incorporating indoor farming at the macro and micro levels in the urban centres can help mitigate this issue.

3 A BRIEF HISTORY OF HUMANS AND PLANTS

It's believed that humans first started domesticating plants (figs) between 11,400 and 11,200 years ago, in an early neolithic town called Gilgal in present day Jordan [3]. Preceding the domestication of cereal by about a thousand years. Around 11,000 years ago humans went from exploiting the earth to actively changing their environment to suit their needs. By intervening in nature, humanity decided to supply their own food, shifting from a nomadic to a sedentary life. And since then, through a process of trial and error, humanity has domesticated plants for their specific function, leading to the development of their civilization. This symbiotic relationship between human and plant eventually brought the plant to be part of the urban landscape. Tales of emperor Nebuchadnezzar (between 605 and 652 BCE) creating the hanging gardens of Babylon to please queen Amytis tells us a lot about plants and the urban realm [4]. To bring plants inside, some cultures have traditions of dwarfing trees for decorative purposes through a process of domestication called Hon-Non-Bo (in Vietnam), Penjing (in China) and Bonsai (in Japan) [5]. As early as 1,000 BCE, plants were used indoors for ornamental purposes in China. Since this was a resource-intensive practice of plant domestication that was not intended for consumption, houseplants were primarily a status symbol. Indoor plants were slower to reach Europe. While many civilizations potted plants, the first indoor plants can be traced back to the Egyptians, Greeks and Romans around 400 BC [6]. Romans used flowers (specially the rose) to beautify the street, eventually bringing them into their villas and bathhouses. During the Renaissance (15th and 16th centuries), sailors started bringing back botanical samples back home starting

a fashion for orangeries and pleasure gardens. Some of these imported plants were not equipped to survive the shift in seasonal weather, so cultivating them entailed a reliance upon heated glasshouses and dedicated gardening staff making of them indoor plants. The first botanical gardens were stablished in the 16th century in Florence (1545), Padova (1545) and Pisa (1544) in Italy. Followed by the Hortus Botanicus Leiden (Netherlands) in 1590, the Botanical Garden of the University of Valencia (Spain) in 1567, Leipzig Botanical Garden (Germany) in 1580, the Botanischer Garten Jena (Germany) in 1586, the Jardin des Plantes de Montpellier (France) in 1593, and the University of Copenhagen Botanical Garden (Denmark) in 1600. Colonialism brough the first botanical garden to India in 1787. In Europe in the 17th century, citrus trees had become a status symbol and with them the green houses needed to let them survive the winter [7]. In 1652, Sir Hugh Platt wrote a popular book called *The Garden of Eden* about indoor plants and gardening popularizing the subject [8]. And after that, greenhouses started popping out all over England. Potted plants became a necessity to bring back to England plants from the colonies. With industrialization during the Victorian era (1837–1901), ordinary homes were beginning to resemble more closely the western homes we know today. Indoor plants had, for the first time, taken root in middle class homes. By then, heated homes allowed for the growth of exotic tropical and subtropical plants. Larger houses were designed with solariums, parlours, conservatories, and green houses where indoor plants became an important part of the décor. Archetypal elements of Victorian architecture like bay windows and sun porches have its origins from the desire for indoors greenery. Plants were inexpensive, brought the outdoors in and could turn any room into a tropical haven. Some of the more popular types of house plants at the time were: The cast iron plant (Aspidistra Elatior), the Boston Fern (Nephrolepis Exaltata), the Kentia Palm (Howea Forsteriana), the Majesty Palm (Ravenea Rivularis), the Jasmine (Jasminum), all of them hardy tropical plants. By the middle of the 19th century gardening books and magazines had indoor plants playing an increasingly important role in interior design. Josiah Wedgwood founded his pottery company in 1759 (England) with an industrialized manufacturing process that catered both to high and low-end clients [9]. During the Art Nouveau period (1890–1910) natured inspired art in all its forms, its asymmetry, variety of textures, subtle colours, and smooth and wavy lines. Artistic motifs were drawn from the richness of native flora and fauna. Art Nouveau's interest in nature, which began at the end of the 19th century, continued into the 20th century until the arrival of modernism. The start of the 20th century saw a shift in attitudes about indoor plants. After the first world war, the minimalistic nature of modernism associated plants with an old-fashioned mentality. The tropical plants made way to more architectural plants like succulents and cacti. Between the 1920s and 1930s modernist architecture working on the interior–exterior spatial connection focused on the architecture–nature relationship. This was specially the case in Scandinavian design, Villa Mairea being a good example, designed by Alvar Aalto in Finland in 1937. Arne Wahl Iversen created furniture pieces that incorporated planters, clearly defining a role for greenery in the interiors they envisioned. Since then, potted plants have been an inherent element in interior design. The internet gave everybody the gardening know-how while technology has made plants cheaper and accessible. With increasing apprehension about climate change and awareness of the wastefulness of consumerism we have experienced a cultural shift towards embracing the natural. Today, seven out of every ten millennials consider themselves a plant parent, meaning someone caring for house plants [10]. Health and wellness are important to the millennial and post millennial generations, plants make healthier spaces by purifying the air, boosting our mood, and lowering our stress. For a generation dependent on social media, sharing platforms like Instagram and YouTube [11] have added a touch of fashion.

Encouraging self-care and nurturing, while creating a community around plants in a world where there is often a disconnect.

4 CAN PLANTS CLEAN THE AIR OF OUR DWELLINGS?

From the building materials to its furniture to all the household products in it, building occupants are constantly exposed to volatile organic compounds (VOC). The accumulation of these chemicals in badly vented spaces are causing indoor air quality problems that contribute to sick building syndrome (SBS) symptoms and other health problems. To reduce VOC from the air, architecture has traditionally used ventilation systems to bring fresh exterior air into the building displacing the stale air from the interior. The more a building ventilates the less SBS incidences. As we rely more on mechanical systems, cost and maintenance make us look towards alternative options to complement them. If indoor air quality is a problem, maybe plants can solve it since that is what they do by being natural filters. A study by NASA [12] found that indoor plants can scrub the air from carcinogens volatile organic compounds. While looking for ways to detoxify interior environments in the international space station, they found that certain plants could remove formaldehyde and benzene from the air. And while this is true in small, sealed chambers over long periods of time, it is not the case on the less controlled conditions of a house. An apartment is constantly exchanging air with the outside, this alone would not give plants enough time to filter chemicals out of the air. Air exchange with the exterior has a greater effect on indoor air quality than plants would. The plants in your home don't get the optimal conditions they would in a lab to maximize photosynthesis improving the plant's toxin-degrading abilities. Indoor plants do not function at a 100% of their ability. So, the answer is that plants can clean the air but in ways that are consequential for indoor inhabitation. This does not mean that indoor plants don't have other benefits, but at this time, it does not look like plants sitting passively in a house are effective enough in purifying indoor air quality [13]. Researchers suggest that you'd have to shelter a large number of plants to equal the air purifying efficiency of modern biofilters and other technologies. So, while air purifying is not really an advantage of having indoor plants, they do benefit our well-being in other ways.

5 SO, THEN WHAT ARE THE BENEFITS OF HAVING PLANTS AT HOME?

While the idea of indoor plants serving as an air purifier for dwellings is a myth, this does not mean that plants don't have other benefits worth considering. Spending time outside in nature has proven to improve our wellbeing [14] by reducing mental fatigue, helping us relax and improve cognition [15]. Although indoor plants are not a substitute for the great outdoors, immersing in nature may not always be feasible or practical. If interacting with plants outside has positive psychological results, these benefits should also manifest indoors. A study about the subject [16] suggests that active interaction with indoor plants can reduce physiological and psychological stress. In a way, plants can make us happy by beautifying our environment. Plants will add colour and liveliness to a space while also serving as noise reduction devices, screens, and dividers. There are also productivity results associated with this sense of calmness were plants in your environments affect your attention [17]. Work performance increases, our work becomes more accurate and of a higher quality when plants are around. And medically, plants in your bedroom or hospital room help you recover faster from illness, injury, or surgery [18]. Caring for a plant can play a role in a person's recovery and provide a sense of accomplishment as you see it grow. There is also a therapeutic side to working with plants where horticultural therapy can be used to increase a feeling of well-being in patients experiencing depression, anxiety, dementia, and other debilitating conditions [19].

Anecdotal and quantitative evidence suggest that humans are innately attracted to nature. In his book *Biophilia* (1984), Edward O. Wilson proposes a reason for our coevolutionary relationship to plants. He proposes that the tendency of humans to focus on, and to associate with nature, this tendency to seek connection with other life forms, has in part a genetic basis deeply rooted in our biology [20]. This hypothesis becomes important in urban environments, where we interact more with technology than nature. Specially after the quarantine of the pandemic where our interaction with other humans diminished. For some, plants substituted our biophilic connection. "The reasons why plants have these psychological benefits for us are still mostly unknown and may go back far in time, bound up in our unconscious awareness that without them, life for our species wouldn't be possible. The calm that pervades us in their presence may be the echo of an ancestral awareness that everything we need and every chance for our survival dwells in the green world. Now as long ago" [21]. And while indoor plants are beneficial to our mental health, they can also help mitigate the food shortages humanity will experience as the population of the planet increases. Urban farming can become an aspect of residential design.

6 HYDROPONICS AND INDOOR URBAN FARMING

Hydroponic agriculture is a relatively new technology that has grown in popularity by providing a faster plant growth rate and a higher yield, while requires less space, no soil, and being water efficient. Hydroponics were invented by William Frederick Gericke (1882–1970) in 1929 at the University of California in Berkeley. The technology was designed to grow plants using a water culture that supplied plants with all the minerals and nutrients that they would otherwise get from soil [22]. He realized that plants could be grown closer together than in soil. And that by adding nutrients and water as the plant grew, he was also able to make them live longer. Modern hydroponics have some advantages over traditional farming, the first is water conservation. Hydroponics use less water because it is recirculated. Only a small fraction of the water gets used by the plant recycling the rest of the water back into the reservoir. As this happens, the water gets constantly oxygenated, optimizing the roots oxygen intake. The process gives the farmer a huge amount of control over his environment by elimination soil-borne pests and diseases and the time it takes to deal with these problems. Today, hydroponic systems are automated and stackable allowing for a vertical far to be much more productive than traditional farming. And by being done locally, removing the long-distance transportation cost from the equation. The system is being used presently in the international space station with plans to be adapted for production on the Moon and Mars [23]. Back on earth these technologies are already being sold off the shelf.

7 GROWING PRODUCE INDOORS AT HOME

So, why have hydroponics farming taken so long in arriving to our homes? The answer is that while they did so in an industrial way, it wasn't until user friendly systems became accessible to the public that we are starting to see its implementation in residential design. Until the appliance became mainstream, alternative versions of the technology remained on the fringe. We are now starting to see big names in home appliances adding kitchen hydroponic units to their line-up. Currently, a company named "Natufia" has what they call a smart garden [24]. An appliance designed to fit a kitchen in the same way a refrigerator could, able to grow 32 plants simultaneously with automatic watering and lighting. Designed to grow leafy greens, microgreens, vegetables, or flowers, offer a selection of 40 different seed pods. Similar appliances, like the "Smart Garden" by Panasonic, the "Home Grow" by GE, the "Smart Indoor Gardening System" by LG, and others made by smaller companies are already in the market. And while the price tag is high, the more these appliances become

mainstream the cheaper they will get. Until that happens people have been adding do-it-yourself vertical farms to their homes. In 2010 an agricultural cooperative in New York City named "WindowFarms" (started by Britta Riley) created a DIY instruction book [25]. The design presented in it was adaptive and meant to fit the typical New York brownstone 4' × 6' window. It is made of recycled plastic bottles and other materials purchased easily at any hardware store. The window farm works by using an air pump to move water with nutrients up to the top of the system. Using gravity, the nutrient rich water trickles down from bottle to bottle accumulating on the bottom where the process starts again. Thanks to this initiative and a DIY YouTube video, people started to build window farms all over the world, and a community was created. They share ideas, test different plants, and share information as a part of a process called R&D-I-Y (research and development do-it-yourself). Through this process the designs keep evolving making it easier for new members that join to build their own. A simple, cheap solution designed to provide fresh local food to people in cities. Weather we look at the high-end or the low-end version, indoor consumable plants have made their way into the home.

8 HOW IS GROWING PLANTS INDOORS SUSTAINABLE?

Sustainability is a word that is thrown around a lot, its meaning is the ability to be maintained at a certain level. In the case of food, it means that we need to grow and produce food in a way that does not deplete our resources while feeding the planet's growing population. The UN expects the world population to reach 8.5 billion by 2030 [26]. And all this people need to be able to produce enough food to subsist. The problem is that our current food production system is unsustainable. We are growing food in deforested land, bathing our crops in toxic pesticides while killing all the wildlife that used those lands previously and then we fly all that food around the world creating a huge carbon footprint for the whole process. China, India, Brazil, and the United States are the four countries that produce the most food in the world. All of them share the advantage of having large populations, a lot of land and different climate zones that allow for a variety of different crops to grow. While Ethiopia, Nigeria, South Sudan and Yemen are the countries with the highest levels of hunger and food insecurity [27]. We are running out of time; we need to figure out how to achieve sustainability for ourselves and for the sake of the environment. Indoor farming can do this in a sustainable way. And it does this first by saving resources, using hydroponic and aeroponic systems uses 90% less water than traditional farming. It also saves land because vertical farming is more efficient, taking less space which could be given back to create nature reserves. Second, we need to shorten the supply chains. If farmers can grow produce indoors, they can do so all year around, lessening the need for importing food from abroad. By buying local, we support the local economy, and the carbon footprint of our food is lessened as is the distance the food travels before it arrives to our plate. Third, because hydroponic and aquaponic systems are set in controlled enclosed environments that use no soil, there is no need for fertilizers. As a side effect, farming will stop killing insects and wildlife. And finally, the controlled environment of indoor farming protects the crop from the weather which will be important as climate change produces more extreme weather around the planet. At a macro level, cities like Singapore are already counting on urban farms to produce 30% of their food by 2030 (presently they produce 10%). Cities around the world are following their example. And while these systems are working at the macro level, a micro version of the same can be implemented on every house, especially in cities, so that families produce a percentage of their plant food helping carry the load from some of the larger systems.

9 WHAT WOULD A HYDROPONIC HOME FARM GROW?

There are many advantages to growing plants hydroponically, some were covered previously but the important one in terms of food production is the speed at which plants grow using this method. Some plants are ready to be harvested 30% to 50% faster than in traditional farming depending on the type of plant. The abundance of nutrients and extra oxygen in the water medium used for this process will also produce larger plants. If agricultural trends continue to erode topsoil and to waste water, hydroponics may soon be our only option. Depending on your socio-economic level you can either buy or build a hydroponic farm. Building a hydroponic setup at home doesn't have to be expensive and it doesn't need to take a lot of space. Here is a list of the best plants to grow hydroponically: basil, beans, blueberries, Boc choy, borage, cabbage, carnations, catnip, chamomile, chervil, Chinese evergreens, chives, cilantro, coleus, cucumber, dahlias, dill, fiddle-leaf figs, geraniums, grapes, hoya, jade, kale, lettuce, lavender, lily of the valley, lotus, mint, orchids, oregano, peppers, petunias, philodendron, pothos, radishes, rex begonia, rosemary, sage, snapdragon, sorrel, spider plant, spinach, spring onions, strawberries, thyme, tomatoes, viola, watercress, watermelon and zinnia. Fig. 1 shows the grow cycle of some of these typical hydroponic crops. Once the setup is ready, it becomes a game of research and experimentation, eventually arriving to the correct type and amount of food one wants to produce for the household. How much of this produce should we feed a person? The number is different in terms of age group, an adult should eat around 600 g of fruits and vegetables per day, this means 18 kg per month. Depending on the size of your hydroponic indoor farm and the amount of people you are feeding, one might or might not be able to achieve this number, but the purpose of indoor farms is to complement your access to fresh produce. And this, it will do at any size. Urban centres around the world suffer from "food deserts", areas where healthy food is either not available or not affordable, hydroponic indoor farming mitigates this issue by giving people the opportunity to have access to good produce at a fraction of the market price, all year round and sustainably.

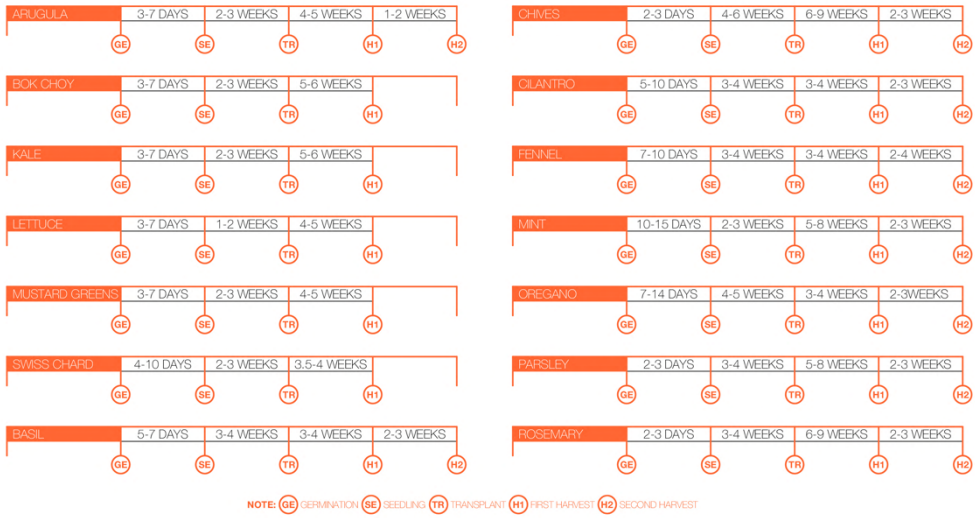

Figure 1: Hydroponic plant growth chart [28].

10 CONCLUSION

As we look into the future of dwelling, humanities coevolution with plants will remanifest indoors out of necessity. In today's fast-paced, digitized world, urban dwellers need to reconnect with nature, with something essential beyond their smart phones and social media. As millennials and post-millennials become plant parents, humanities coevolution with plants strengthens. In interiors, this relationship is more than a design aesthetic, it has complex health benefits and the potential to give people food security. As apartments and houses become sanctuaries from a fast-paced world, a place where indoor plants help enhance our mood, productivity, concentration, and creativity, while dispelling loneliness and depression, we find that indoor plants make us happier by improving our wellbeing. If on top of that they can help prevent hunger, then it is imperative to strengthen our biophilic relationship with indoor plants out of a need for survival. Hydroponic farming is not a future trend but a necessity. It is currently being taught in classrooms around the world, horticultural societies and it is being funded in government research at universities and organizations like NASA. But that is not enough, hydroponics needs to move indoors as part of interior design. So, it can help achieve food equity and the prevention of hunger, helping strengthen the United Nations sustainable development goals two, three, ten and seventeen [29]. The future of dwelling depends on plants becoming part of the interior architecture in urban centres where the city and the farm can intermix. If we are going to spend a large portion of our time indoors, whether at work or in our homes, we might as well benefit from the experience by doing so in interiors designed to better our quality of life.

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REFERENCES

[1] United Nations, Department of Economic and Social Affairs, Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion by 2100, 2019. https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html. Accessed on: 11 Jun. 2022.

[2] Ranganathan, J., Waite, R., Searchinger, T. & Hanson, C., How to sustainably feed 10 billion people by 2050, in 21 charts, 2018. https://www.wri.org/insights/how-sustainably-feed-10-billion-people-2050-21-charts. Accessed on: 11 Jun. 2022.

[3] Kislev, M.E., Hartmann, A. & Bar-Yosef, O., Early documented fig in the Jordan Valley. *Science*, **312**(5778), pp. 1372–1374, 2006. DOI: 10.1126/science.1125910.

[4] Cartwright, M., Hanging Gardens of Babylon, 2018. https://www.worldhistory.org/Hanging_Gardens_of_Babylon/. Accessed on: 10 Sep. 2022.

[5] Van Lit, P. & Buller, L., *Mountains in the Sea: The Vietnamese Miniature Landscape Art of Hon Bo*, Timber Press, 2005.

[6] Perrott, R. & Byrd, A., Houseplant, 2020. https://www.britannica.com/science/houseplant. Accessed on: 11 Jun. 2022.

[7] Valen, D., On the horticultural origins of Victorian glasshouse culture. *Journal of Society of Architectural Historians*, **75**(4), pp. 403–423, 2016. https://www.jstor.org/stable/26418938.

[8] Platt, H., The Garden of Eden: An accurate description of all flowers and fruits now growing in England, with particular rules how to advance their nature and growth, as well in seeds and herbs, as the secret ordering of trees and plants, EEBO Editions, ProQuest, 2011.

[9] Mann Jackson, N., 250 years of Wedgwood: Two new exhibitions celebrate the enduring wares of ceramics designer and entrepreneur Josiah Wedgwood, *Smithsonian Magazine*, 2009. https://www.smithsonianmag.com/arts-culture/250-years-of-wedgwood-143057153/. Accessed on: 10 Sep. 2022.
[10] Article, Survey: Decorating with houseplants, 2020. https://www.article.com/blog/survey-decorating-with-houseplants/. Accessed on: 11 Jun. 2022.
[11] Cottrell, A., The indoor gardening trend that is surging in popularity in Instagram, 2021. https://www.gardeningetc.com/news/indoor-gardens-are-in-high-demand. Accessed on: 11 Jun. 2022.
[12] Wolverton, B.C., Douglas, W.L. & Bounds, K., Interior landscape plants for indoor air pollution abetment, 1989. https://ntrs.nasa.gov/citations/19930072988.
[13] Cummings, B.E. & Waring, M.S., Potted plants do not improve indoor air quality: A review and analysis of reported VOC removal efficiencies. *Journal of Exposure Science and Environmental Epidemiology*, pp. 253–261, 2020. DOI: 10.1038/s41370-019-0175-9.
[14] White, M.P., Alcock, I., Wheeler, B.W., Hartig, T., Warber, S.L., Bone, A., Depledge, M. & Fleming, L.E., Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Scientific Reports*, **9**, 7730, 2019. DOI: 10.1038/s41598-019-44097-3.
[15] Bratman, G.N., Daily, G.C., Levy, B.J. & Gross, J.J., The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, **138**, pp. 41–50, 2015. https://www.sciencedirect.com/science/article/abs/pii/S0169204615000286.
[16] Lee, M., Lee, J., Park, B. & Miyazaki, Y., Interaction with indoor plants may reduce psychological and physiological stress by suppressing autonomic nervous system activity in young adults: A randomized crossover study. *Journal of Physiological Anthropology*, 2015. DOI: 10.1186/s40101-015-0060-8.
[17] Raanaas, R.K., Evensen, K.H., Rich, D., Sjostrom, G. & Patil, G., Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology*, **31**(1), pp. 99–105, 2011. DOI: 10.1016/j.jenvp.2010.11.005.
[18] American Society for Horticultural Science, Flowering plants speed post-surgery recovery, 2008. www.sciencedaily.com/releases/2008/12/081229104700.htm. Accessed on: 11 Jun. 2022.
[19] De Seixa, M., Williamson, D., Barker, G. & Vickerstaff, R., Horticultural therapy in a psychiatric in-patient setting. *BJPsych International*, 2017. DOI: 10.1192/s2056474000002087.
[20] Wilson, E.O., *Biophilia*, Harvard University Press: Boston, 1984.
[21] Mancuso, S. & Viola, A., *Brilliant Green: The Surprising History and Science of Plant Intelligence*, Island Press, p. 44, 2015.
[22] Gericke, W.F., *The Complete Guide to Soilless Gardening*, Kessinger Publishing, Montana, 1940.
[23] Dunbar, B. & Heiney, A., Growing plants in space, 2021. https://www.nasa.gov/content/growing-plants-in-space. Accessed on: 11 Jun. 2022.
[24] Natufia, Meet Natufia Smart Garden, 2022. https://natufia.com/product/natufia-smart-kitchen-garden/. Accessed on: 11 Jun. 2022.
[25] WindowFarms, Version 3.0-DIY Instruction Book, 2018. http://www.windowfarms.nl/wp-content/uploads/2018/03/Version-3.0-DIY-Instruction-Book.pdf. Accessed on: 11 Jun. 2022.

[26] United Nations, World Population Prospects 2019: Highlights, 2019. https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf. Accessed on: 11 Jun. 2022.
[27] Food and Agriculture Organization of the United Nations, Hunger hotspots: FAO-WFP early warning on acute food insecurity, 2022. https://www.fao.org/3/cb8376en/cb8376en.pdf. Accessed on: 11 Jun. 2022.
[28] Zipgrow, Best crops for hydroponics guide, 2020. https://zipgrow.com/wp-content/uploads/QuickCropsGuide.pdf. Accessed on: 11 Jun. 2022.
[29] United Nations, Transforming our World: The 2030 Agenda for Sustainable Development, 2015. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. Accessed on: 11 Jun. 2022.

EVOLUTION MECHANISM, HISTORY AND CHARACTERISTICS OF CHINA'S RURAL AREAS SINCE THE REFORM AND OPENING-UP

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ABSTRACT
During the rapid urbanization of the past four decades, the countryside has been continuously evolving. The adaptation of the constantly diversified needs of people and the highly competitive space between urban and rural areas determines people's urbanization choices; and the core factors affecting the direction of rural evolution in the characteristics of rural itself are geographical location and resource endowment. Under the combined effect of people's urbanization choices and rural characteristics, Chinese rural areas are constantly evolving in terms of population, function and space. By analyzing rural cases at different stages, the paper points out that rural areas have experienced three stages: rural industrialization in local urbanization, rural shrinkage and remote urbanization, and rural multi-dimensional reconstruction in high-frequency mobile urbanization, revealing the law of rural evolution: only villages that can meet people's diverse needs and adapt to people's urbanization choices can develop and evolve healthily and sustainably.
Keywords: urbanization, rural area.

1 INTRODUCTION

The birth and maturity of Chinese civilization is based on the developed farming culture. For a long time, the continuation of farming culture has made the countryside the cornerstone of the inheritance of Chinese civilization. "Chinese society is countryside" [1]. However, the advent of industrial civilization has profoundly changed the relationship between urban and rural areas, making the stable social structure of "farming for a living, handed down from generation to generation, and rarely changed" [1]. Flow freely between urban and rural areas, and the vigorous urbanization process begins.

The process of rapid urbanization in the forty years since China's reform and opening up is also the process of urbanization. "Urbanization" is not a simple phenomenon of macro-population mobility [2], [3], and it is not only a consensus on the concept of urban governance [4], [5],but a process of social change that actually occurs in urban and rural areas based on the real needs of countless individuals. During this process, great changes have taken place at both at the urban and rural areas: on the one hand, cities and towns have rapidly expanded land use, improved spatial quality, and increased economic volume, but they are faced with urban problems such as traffic congestion, disorderly sprawl, and semi-urbanization; on the other hand, The villages are shrinking, transforming, and they are also constantly evolving. Today, the villages can no longer be crop production base [6], and the value of the villages is being re-recognized and evaluated by the academic community [7]–[9]. What drives the evolution of the countryside? What role will the countryside play in the urban–rural system? Fundamentally speaking, the core driving force of rural evolution originates from the process of urbanization. Based on the perspective of human urbanization, this paper attempts to review the mechanism and process of rural evolution in my country since the reform and opening up, and proposes an approach to rural evolution on the basis of summarizing its evolution characteristics.

2 RURAL EVOLUTION MECHANISM FROM THE PERSPECTIVE OF URBANIZATION

People's urbanization choices and rural characteristics together constitute the dynamic mechanism of rural evolution. People's urbanization choices are the characteristics and trends of social population mobility in a certain era based on real needs. The rural characteristics are the unique space and resource elements of the village itself, such as scenic resources, tourist attractions, characteristic crops.

At the same time, the process of urbanization is essentially a process of mutual adaptation between individual needs and various spaces with different competitiveness, which determines people's urbanization choices. Maslow's pyramid model of human needs, show that human needs present a hierarchical structure, and in general, human needs satisfaction presents a priority order from the basic level to the high level. Based on Maslow's pyramid model of human needs [11], combined with the actual situation in the process of urbanization, the pyramid model of human needs in the process of urbanization is constructed (Fig. 1). The hierarchy of people's needs match urban and rural spaces with different competitiveness, which determines people's urbanization choices.

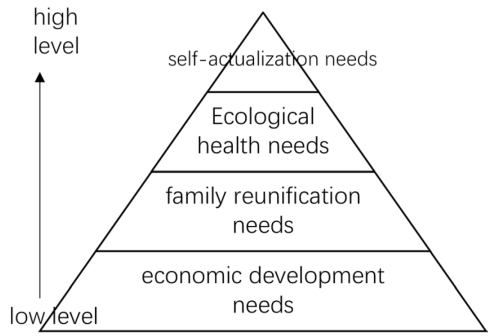

Figure 1: Pyramid model of human needs in the process of urbanization. (Source: Author's redraw from Maslow's Pyramid of Needs Model.)

The decisive elements in the rural characteristics are "geographical location" and "resource endowment". The "geographical location" of the countryside determines its connection with the surrounding cities or small towns in economy, culture, transportation, etc., determines whether it can undertake the information, capital, industry from the city. The "resource endowment" level of the countryside includes not only specific ecological resources such as forests, wetlands, farmland, minerals, mountains and rivers, but also social resource elements represented by population, labor force, and some characteristic culture and other resource elements.

The content of rural evolution includes three aspects: function, population, and space. In rural evolution, the first thing that often happens is the change of population composition, either outflow or inflow. The transformation of rural functions means from a traditional agricultural village to a new industrial village or a tourist village. With the period, the rural spatial characteristics and spatial features usually change accordingly.

Over the past 40 years in China, people's choices for urbanization have changed. The development of society has changed people's urbanization needs and urban–rural space competitiveness. In fact, the characteristics of rural are also affected by the process of social

development, the compression of time and space brought by high-speed rail network and high-speed network [12] has reshaped the geographical location of rural areas in a sense. The value of various resource elements is also re-evaluated as people's needs change. The combination of people's urbanization choices and rural ontological characteristics constitutes the dynamic mechanism of rural evolution, thus promoting the transformation of rural areas in terms of population, function, and space (Fig. 2).

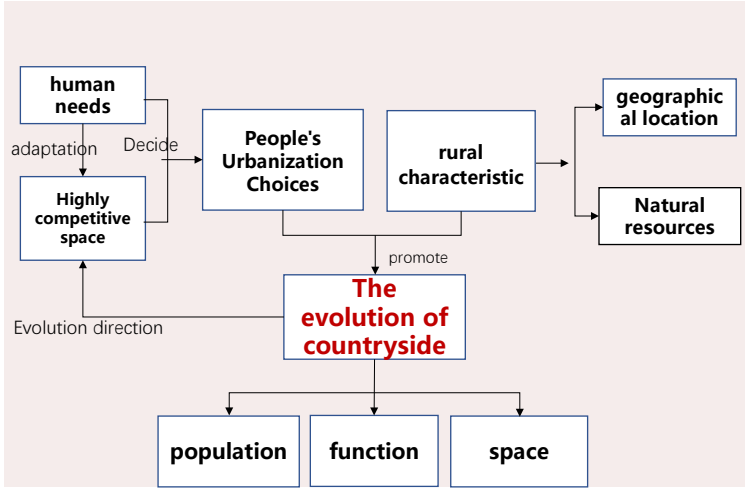

Figure 2: Rural evolution mechanism from the perspective of human urbanization.

3 RURAL EVOLUTION PROCESS FROM THE PERSPECTIVE OF URBANIZATION

3.1 1978 to the 1990s: Rural industrialization in local urbanization

In December 1978, China made a historic decision to transfer the work to economic construction and implement reform and opening up. After a long period of lack of material wealth and even absolute poverty, economic development and demand for material wealth have occupied the main position in people's urbanization needs. There is no doubt that the grass-roots practice of China's reform and opening up began in the countryside. A series of rural system reforms, such as unified purchase and sales policy, liberated the rural productive forces [13], the huge demographic dividend in urbanization appears. In the early days of reform and opening up, cities still strictly restricted the free flow of rural population to cities, and rural surplus labor could not freely enter cities to complete urbanization; The industrial structure dominated by heavy industry, and the rigid production system with no separation between government and enterprise, which could not meet the huge demand for consumer goods in the society. It provided conditions for the transformation of rural industrialization and the development of rural enterprises.

In rural areas, small enterprises with villages as units have developed rapidly in southern China. In these areas, local urbanization under the guidance of rural industrialization has become the mainstream choice for people's urbanization: people's economic development and material wealth needs and emotional needs for family reunion can be satisfied at the same time. In addition to large cities, industrialized villages have become highly competitive

spaces for human urbanization at this stage. Very famous industrial villages such as Huaxi Village and Yonglian Village were born.

As far as the characteristics of the village itself are concerned, these villages that rely on township enterprises to complete the rural industrialization are often located in the Yangtze River Delta urban agglomeration, the Pearl River Delta urban agglomeration regions. These major urban agglomerations have a good industrial foundation; It is closely connected with the city, and can actively undertake industrial equipment and technical concepts from the city's spillover, and its products can also be sold to the city smoothly through relatively convenient transportation; in terms of resource endowment, the area where the industrial village is located is often crowded. Sufficient, with obvious advantages in labor resources. The villages that have evolved into industrial villages have achieved structural changes in the population from agricultural populations to industrial workers; functionally, they have transformed from agricultural product production to industrial product production, playing the role of urban consumer goods "production workshops" (Table 1).

3.2 Early 2010s to the present day: Multidimensional reconstruction of rural areas in the process of high-frequency mobile urbanization

In the early 2010s, China's urbanization rate had exceeded the critical point of 50%. After more than 30 years of continuous economic and social development, people's lives have become increasingly rich. In 2018, the per capita disposable income of national residents was 28,228 yuan. The per capita disposable income of urban residents was 39,251 yuan, a real increase of 5.6%; the per capita disposable income of rural residents was 14,617 yuan, a real increase of 6.6%. The gradual satisfaction of material wealth and economic development makes people's needs change. People's urbanization needs are characterized by diversification and high-level characteristics, and ecological and healthy livable needs are prominent – green and livable, and a beautiful ecological environment is generally pursued by people. In addition, the highest level of people's needs in urbanization is also the realization of self-worth, such as the pursuit of cultural belonging, spiritual belonging and the value of life. These high-level demands can no longer be satisfied in cities where efficiency is paramount, with high construction density, separation from the natural environment, and atomization of social structures.

People turn their attention to the countryside and begin to re-examine the ecological value and Cultural Value. While people's needs are changing, the time and space compression brought about by the construction of high-speed railway and other high-speed transportation networks makes the flow of factors between urban and rural areas more frequent. People's urbanization choices are freer. High-frequency urbanization model: urban residents no longer regard rural areas as synonymous with backwardness and poverty. Traveling to rural areas for tourism, vacation, leisure and entertainment, meetings, and even buy a second home has become a new choice for the urban middle class ; Residents also enjoy all the public and commercial services in the city between urban and rural areas.

At this stage of high-frequency mobile urbanization, the emergence of tourist villages, gentrified villages, and even e-commerce villages all represent the trend of rural evolution in the new era. Tourist villages often have good ecological landscape resources or historical and cultural resources in terms of their rural characteristics. At the same time, they are located in the metropolitan area, with convenient transportation and convenient transportation for urban residents; functionally, tourist villages changed from rural areas to rural tourism resorts. The population, on the one hand, it attracts people to return to the tourism service industry; In

Table 1: 1978 to the early 1990s: Rural industrialization in local urbanization.

Village type	People's urbanization needs	People's urbanization choices	Characteristics of rural		Evolution of rural		
			Geographical location	Resources endowment	Population	Function	Space
Industrial village	Economic development and material wealth needs The emotional need for family reunion was ignored	Local urbanization	Convenient transportation	Advantages in labor resources	Complete the non-agricultural occupation on the spot	A "production shop" for urban consumer goods	Factory, land fragmentation

terms of space, there are features such as scenic spotting and refinement. During this stage, a number of star tourism villages emerged, such as the "Five Golden Flowers" Farmhouse Village in Chengdu, Sichuan province; Yuanjia Village in Xianyang, Shaanxi province, and the beautiful "Five Golden Flowers" villages in Jiangning, Jiangsu province.

Gentrification villages are similar to tourist villages. They have good ecological landscape resources and good traffic locations in the metropolitan area. With the outflow of rural population and private transactions and contract rentals of idle homesteads, some villages with good resource backgrounds will accompany them. With the influx of the urban middle class, it has evolved into a gentrified village : functionally, it is a high-end residential area as the second residence of the urban middle class; at the same time, the population is reconstructed, with a significant gentrification. In terms of spatial characteristics, it has undergone a refined transformation to cater to the aesthetics of the middle class.

The e-commerce villages are produced with the popularization of the Internet and logistics networks between urban and rural areas. The role of the Internet enables villages to break through geographical barriers to a certain extent, and geographical location constraints are no longer a decisive factor, through engaging in e-commerce, the characteristic resources and products of the village itself can be tapped, and the evolution from rural to e-commerce village is realized: in terms of population, villagers have completed the occupational change of engaging in local business services; in terms of function, they have become In terms of form, it can maintain the landscape features of low construction density and good ecological environment in rural areas (Table 2).

4 CHARACTERISTICS AND DIRECTION OF RURAL EVOLUTION IN CHINA

4.1 Characteristics of China's rural evolution

Throughout the four decades of reform and opening up, the rural evolution process, starting from the development of township enterprises, the transformation of rural industrialization under the guidance of local urbanization. Later the duality between urban and rural areas, hollow villages and urban villages emerged from the urbanization model in different places; and later, high-frequency urbanization tourist villages and gentrification villages appeared. The evolution process of the urbanization process is deeply related to people's urbanization choices and the needs of people behind them and the changes in the competitiveness of urban and rural spaces; at the same time, the elements of rural ontology, as the inherent genes of rural inheritance, are selected in different stages of urbanization. The expression of sexuality guides the village to complete the evolution. With the development of economy and society, the level of people's urbanization needs has become increasingly diverse, the spatial competitiveness of urban and rural areas has been reshaped, and people's urbanization choices have changed from local urbanization, off-site urbanization, to today's new stage of high-frequency mobile urbanization; In the process of rural evolution and transformation, the rural population has changed from agricultural population to non-agricultural population, from closed community to open community; rural functions have transformed from single agricultural production to multiple complex functions; rural space has changed from rural features From the loss of urbanization construction, to the return of low-density, high-quality, ecologically livable space. The history of rural evolution over the past 40 years of reform and opening up reveals this law: Only the villages that can meet people's diverse needs and adapt to people's urbanization choices can continue to evolve and develop healthily and sustainably in the drastic social environment.

Table 2: Early 2010s to the present day: Multidimensional reconstruction of rural areas in the process of high-frequency mobile urbanization.

Village type	People's urbanization needs	People's urbanization choices	Characteristics of rural		Evolution of rural		
			Geographical location	Resources endowment	Population	Function	Space
Tourism village	Presenting diversified and high-level features:	High-frequency and mobile urbanization	Within metropolitan areas	Good ecological landscape resources	Non-agricultural employment	Rural tourism resort	Scenic and refined
Gentrified village	The livable needs of ecological health, and individual self-actualization needs		Within the metropolitan area	Good ecological landscape resources	Gentrification	Upscale settlements for the middle class	Refinement
E-commerce village			–	Special products	Non-agricultural employment	Business space in the internet	Traditional rural settlement forms

4.2 The direction of rural evolution in China

In the new era of high-frequency mobile urbanization, the final direction of the healthy evolution of the countryside is to become a highly competitive space in the urban–rural network that can meet the diverse needs of people; and this process still requires the active participation of China's urban planning community to give rural Orderly guidance to avoid passive decay and disorderly alienation in the countryside. First of all, it is still necessary to comply with the trend of the continuous growth of urbanization rate and the continuous shrinkage of a large number of agricultural villages; in 2021, the urbanization rate of permanent residents in China has reached 63.89%, but it is still 75–80% away from the completion of urbanization in developed countries. There are still distances, and hundreds of millions of rural people will still go to cities in the future; differentiated policies should be formulated to actively guide them according to the different characteristics of the village itself, so as to prevent the resource investment in the process of rural revitalization from producing pepper-sprinkled egalitarianism. Secondly, in line with the background of high-frequency mobile urbanization in the new era, from the perspective of the diverse needs of people in urbanization, combined with the ontology characteristics of the countryside, rethink and evaluate the function and value of the countryside in the high-mobility urban–rural network structure. In the new era, we must pay special attention to the green, livable, and human-centered spatial environment in the countryside, and the relationship between nature and man that is closely related to nature; pay attention to rural space as the carrier of traditional agricultural civilization and the inheritance of farming culture; pay attention to the traditional construction of rural areas. And the wisdom of flexible governance with "small community" as the unit; attach importance to the stable community structure in the countryside, and give people a sense of spiritual belonging in the inheritance of good rural culture. Actively implant environmentally friendly emerging functional formats to guide the healthy development and evolution of qualified rural areas. Finally, further break down the institutional barriers between urban and rural areas, fully guarantee the free flow of resources and factors between urban and rural areas, actively and orderly guide the flow of people, capital, and information from the city into the countryside, revitalize the idle resources in the countryside, and promote the healthy evolution of the countryside. Help and empower rural revitalization.

REFERENCES

[1] Tong, F.X., *Rural China*, Shanghai People's Publishing House, pp. 12–14, 2019.
[2] Yong, Q.X., The changing process of "urbanization of people" and "urbanization of things": 1978–2011. *Reform*, **2014**(4), pp. 88–99, 2014.
[3] Yuan, R., Urbanization of people: Research on the essence of new urbanization. *Fudan Journal (Social Science Edition)*, **56**(4), pp. 134–139, 2014.
[4] Nian, L.H., Talking about "urban people" again: People-oriented urbanization. *Urban Planning*, **38**(9), pp. 64–75, 2014.
[5] Miao, W.Y., The basic connotation and realization conditions of human urbanization. *Urban Issues*, **9**, pp. 4–10, 2016.
[6] Jingxiang, Z., Mingrui, S. & Chen, Z., Rural Revival: China's rural transformation under productivity and post-productivity. *International Urban Planning,* **29**(5), pp. 1–7, 2014.

[7] Mingrui, S. et al., Re-discrimination of Chinese rural cognition from a comparative perspective: Contemporary value and rural revival. *Human Geography*, **30**(6), pp. 53–59, 2015.
[8] Guohua, Z., Liuyan, D. & Yanhua, H., On rural multifunctional evolution and rural settlement transformation. *Chinese Journal of Agricultural Engineering*, **36**(19), pp. 242–251, 2020.
[9] Hong, Y. et al., Urban and rural equivalence: A new path for rural development in the new era. *Journal of Urban Planning*, **3**, pp. 44–49, 2021.
[10] Tianlin, W., The triple nature of human existence, essence and liberation. *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition)*, **4**, pp. 3–5,1998.
[11] Wanzhong, H., Talking about people's value and self-worth from Maslow's theory of needs. *Nanjing Social Sciences*, **6**, pp. 25–29, 2000.
[12] Jianhui, F., A brief analysis of Harvey's "Space–Time Compression". *Theory*, **7**, pp. 33–37, 2010.
[13] Yibo, Q., The evolution process, characteristics and direction of China's urbanization since the reform and opening up: From the perspective of population, economy and system. *Urban Planning*, **44**(1), pp. 44–51, 2020.

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SUSTAINABLE HABITAT: LITERATURE REVIEW AND INSIGHTS

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ABSTRACT
This study focuses on different forms of housing in Tunisia and their various types of construction. It seeks to better understand the phenomenon of traditional and modern housing for the purpose of potentially reshaping the way we build in a particular context. This study provides a realistic solution for accommodation, and it explains how to think about housing differently in order to live together more effectively and to reflect an ideal evolutionary and ecological approach to architecture for future living spaces. This research shows that housing can reflect new social and community lifestyles and can also develop and adapt to economic, environmental, and social needs. Furthermore, the basic premise of the city of the future is to involve humans with the design process and to develop social exchange by promoting social connectivity around concepts for new design intentions such as smart buildings that are connected, modular, eco-responsible and respectful of the environment.
Keywords: living collectively, grouped housing, evolutionary approach, adaptability, ecological.

1 INTRODUCTION

Shelter is a basic human need that is crucial for survival. It provides security, personal safety and protection. Adequate housing provides people with the opportunity to lead normal lives and to establish their place in a community. We all carry the need "to be and do with space" [1]. Since the dawn of time, inhabiting a space has been one of the major human concerns that has generated, throughout the history of humanity, several possibilities for housing and shelter while integrating it into nature. In fact, humans deployed their intelligence in order to build their living space by adapting it to the environment and the climate [2]. From the caves of the nomads to the buildings of the 20th century, habitat has never ceased to reinvent itself to respond to human needs under different conditions. Between the traditional and modern structures, they both represent pioneering fronts in ways of living and valuable responses to different contexts.

However, what does inhabiting mean? What are the various forms of housing in Tunisia? How can we improve the current situation of this heritage, and what is the ideal image of housing for the future? How can we design a scalable and adapted housing model? How can we rethink the status of the individual house? How can we live collectively?

2 TUNISIAN CONTEXT

As is seen by its architecture and the way of occupying the space in different geographical areas, urban housing in Tunisia is a response to a specific context by adapting it to the environment as well as to the climate. The climate has a considerable influence both on the type of the materials available in each region and on the type of building itself in order to guarantee adequate housing for the site and the way of living of its inhabitants. Nowadays, the development of technologies has generated new materials and new forms of implementation. They do facilitate daily life, but unfortunately, they are neither environmentally friendly nor suitable for society's needs.

2.1 Habitat adapted to the environment

Through analyses of the Tunisian context, housing has taken several forms. They used to be simple shapes (either squares or rectangles) such as houses with patios in the medinas, the vernacular Djerbian houses and the troglodyte constructions in Matmata, etc. The forms of habitat have always been diversified and their characteristics have always been very particular and unique, but very well adapted to various climates (arid, Mediterranean, etc.) and different geographical contexts (mountains, desert, seacoast, etc.). In the case of Matmata in Tunisia, its troglodyte people took advantage of the area's topography to build shelter underground by digging into the rock on the mountainside or by digging vertically into the earth and creating large wells.

In these regions, temperatures climb to unreasonable heights, so their inhabitants utilized construction methods to create shade and increase coolness [2] through (1) earthen and stone structures well known for heating up slowly during the day and cooling down slowly at night; (2) structures with thick walls with only a few small openings in order to maintain a relatively stable interior temperature; (3) the white facades and domes that reflect ultraviolet rays; (4) narrow streets and closely placed houses that are organized to reduce the surface area of the walls exposed to the sun in order to decrease the temperature inside the house and provide shade outside; and (5) patios (the houses built around inner courtyards which existed in Mesopotamia, 6,000 years ago, and which we find in Egypt, China, Greece, the Roman Empire and in South America), allow a microclimate inside the house and four walls protect it from the sun. This space maintains fresh air throughout the day that has accumulated during the night and filters the direct sunlight to the interior using the Mashrabiyas. The freshness of the patios is reinforced by the presence of water fountains and plants. As for roofs, similar to patios, they are dedicated to exchange between family members and neighbors where they meet, eat and even sleep when the nights are too hot. The roofs are also considered a livable exterior space. Overall, the traditional Tunisian habitat is an interesting example of an ecological and bio climatical architecture. It reflects not only living collectively, conviviality, solidarity and exchange between inhabitants but also a specific culture and architectural identity.

Figure 1: Traditional house with inner courtyard [3].

2.2 Standardized modern housing

Nowadays, structures have taken on complex and sophisticated forms as the results of adding or subtracting simple forms such as colonial houses, villas, apartment buildings and slums. Today's housing in Tunisia has several advantages such as vertical extensions, contemporary features, comfortable equipment, and high security features. Unfortunately, the way we currently think about collective housing has negative consequences. It is difficult to find accommodation in the metropolitan areas. The spaces are small and not affordable. The housing model is standardized, there is a lack of identity and social interactions, and it does not promote cohabitation and social collectivity.

The same building model is designed all over the continent. It is not related to geography, history and location. On the one hand, it is only a question of standardizing apartments in buildings, and on the other hand, of juxtaposing individual houses over kilometers. Additionally, existing buildings are demolished, and natural spaces are destroyed in order to apply the current model. Nowadays in Tunisia, housing is often the adaptation of the European, modern, universal model to different constraints within global typologies. The only interest is for facades and the outer shell. The main goal is to design the shell of the project in order to create a striking and attractive facade and ignore the rest of the design process. This approach tends to reduce the current housing model to a standardized design, disconnected from its context. It does not take into consideration the two fundamental elements of housing such as the inhabitant and its context. While they are not totally ignored, they are in fact involved in an abstract way and as quantitative criteria. They are known as modern buildings in reference to "Le Corbusier", but they are not on stilts, do not utilize an open plan or long windows, nor an outside terrace. They are built as quickly as possible on vacant sites without taking into account urban planning policies. Architects are asked to build small cubes at a given location with a given number of floors, given facades, standards with a series of constraints that limit creativity and new ways of thinking. It is in fact an absolute design cloning by using software to design a building that uses the same process and only modifies a few parameters from one design to another. Today, we are facing homogenization, standardization, and insensitivity in our approach to urban housing, resulting in a loss of cultural identity.

Figure 2: Collective habitat in Tunisia [4].

Rym Zaabar, general architect, in the urban planning department of the ministry of equipment, affirms that urban planning tools do not make it possible to take into account the differentiated situations of cities. Too prescriptive and standardized, they lack the flexibility needed to adapt to local specificities. The result is due not only to a lack of political will and involvement of civil society, but also to the absence of planning tools commensurate with the issues in question [5]. Bessaad confirms that operational urban planning tools are standardized and do not sufficiently take into account the diversity of situations and realities. The PAU is more like an urban planning document. It is a very rigid document with binding provisions. The revision process, extremely long and complex, weighs down and even slows down, the slightest modification [6].

Nowadays, we are questioning the design process of housing. It is often neither adapted to social and demographic changes, nor adapted to climate issues. Therefore, it is necessary to revise our habitat design process so that it can respond to the actual economic, environmental and social needs. In this regard, the main questions are the following. How to offer collective housing with higher quality of use and flexible standards for individualized homes? How to rethink the status of the individual house and living collectively? How to reinvent the way we live and how we build? How to involve inhabitants within the design process? How to think about urban density in a sustainable way?

3 TOWARDS AN EVOLUTIONARY APPROACH TO ARCHITECTURE

Establishing sustainable and treasured cities is not a luxury requirement but a right for every citizen, and this vision engages the architect within the design process in regard to the urban environment. Due to a variety of new research and perspectives about the concept of habitat, some reflections have revolutionized the way of living and building around the world. These reflections have tried to improve and renovate the habitat of today as well as to promote living together and making urban housing flexible for its inhabitants and adapted to the evolution of families and to climate changes.

3.1 Reliving the past and involving people within the design process

The architect is asked to design and get the inspiration from the past and to understand the present to conceive the future. To continue to build and renew without expanding, this is the challenge of the cities for the future. That is why the renovation and expansion of buildings are becoming options increasingly considered by project owners. Solutions can make it possible to build affordable housing, but also can offer new perspectives for old buildings. “Not to impose, not to destroy, but rather to reveal, consolidate and improve”, this is the belief of the architect Christophe Hutin who for more than 20 years has been critically reflecting on the evolution of the city and its systemic exclusion and segregation within habitats [7]. His main goal is to help residents regain control of their built environment to better appropriate their cities. This will enhance better living, sharing and social exchange.

Such is the example of the project entitled “Transformation of 530 dwellings Grand Parc Bordeaux”, which won the EU Mies Award, and was realized by Lacaton and Vassal Architects, Frédéric Druot Architecture and Christophe Hutin Architecture. These three architectural firms managed to transform the apartments and improve space and services while keeping construction costs as low as possible; so much so that it was not necessary to increase the rent for tenants – but above all, the residents were not forced to leave their homes during the work, thus minimizing the inconvenience. The architects also provided the apartments with balconies and verandas, considerably increasing the amount of natural light in each unit [8].

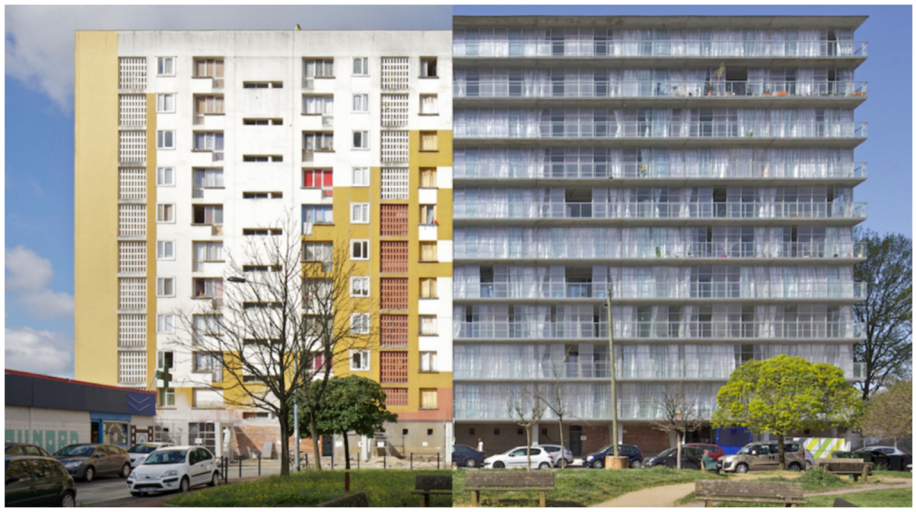

Figure 3: Transformation of 530 dwellings by Lacaton and Vassal, Druot, Hutin, Bordeaux, France, 2017. *(Source: Lacaton and Vassal Projects.)*

Christophe Hutin also tried to reinvent the profession by not finishing the project, and it was up to its inhabitants to write their own story and finish conceiving their homes. According to Hutin, a flexible and simple architecture allows appropriation. Hutin involves the inhabitant within the design process. In Bègles, for example, with his collaborators, he thought of a project with a vertical subdivision, creating a shelf for houses. A minimalist concrete structure integrating canalization and piping giving the opportunity to its inhabitants to build their own houses in a restricted volume. They designed a concrete structure so people could buy a volume and build a two-story house with an architect or to do a self-built [9]. From an economic point of view thanks to this project, it is now possible to buy real estate in an urban environment at the equivalent price of a plot of housing estate far from the center. This project is about individuality, not to be confused with individualism. It provides a home that is appropriate for human needs while contributing to a comfortable, dense and accessible city; a place where we spatially experience our individuality on a daily basis, but also our relationship with others, family, neighbors, neighborhood and the society in general.

Figure 4: The highlands by Christophe Hutin [9].

Building with the people and for the people was the main concern of Hassan Fathy, precursor and visionary of vernacular architecture, at the service of human beings [10]. Hassan Fathy developed a whole philosophy of living based on the reuse of ancestral construction techniques in order to design a new vernacular language. This architecture involves humans with the design process. Fathy affirms the value of the identity of each country or urban space and its unique character to ensure a unique habitat specific to each context. That is why he proposed the reuse of old construction methods to build the village of Gourna by using innovative construction processes and guaranteeing the authenticity of the local architecture and the cultural values of the village.

Rethinking housing design begins with understanding the lifestyles of its inhabitants and its environment by taking into account the climate, culture and the local materials available on site, making them an asset. In fact, the climate has a considerable influence on the type of building and materials in each region. Additionally, this allows for effective ergonomic and thermal management of the space.

3.2 Living collectively and developing social exchanges

Due to the housing crisis, demographic growth and ecological and economic crises, it is essential to rethink expensive housing, which can be standardized and disconnected from its environment, and consider new forms of grouped housing. In fact, grouped housing promotes living together, cohabitation and social exchanges between inhabitants. Co-housing, grouped housing or participatory housing are new ways of living collectively. It is in fact, highly developed in Europe. Living together and shared housing are the basis for each project. From kangaroo housing to senior-student shared accommodations or inter-generational buildings, there is a need to think about housing with elderly people and not just for the elderly. Let's consider a group of people (elderly people, young couples, families, singles) who want to live in affordable housing on a low budget in a good location that is eco-responsible and that can evolve with the needs of each family. They can live in a community, share life between themselves and be promoters of their own projects. The cooperatives are formed not only by an architect to design the project and lead the construction site, but also by a project management assistant to lead the project [11]. In cooperation with these experts, the future inhabitants meet regularly to create their residence and promote living together in individual houses. They all agree with this principle of life by acting responsibly and inventing new uses and shared spaces. It is a way of living based on social diversity and exchange between neighbors with a common house "meeting place": a way of life based on human dimension of sharing expertise and transmitting it from one generation to another. They know each other very well. It is a collective habitat where they share a lot of conviviality, solidarity and a neighborhood. Sharing your home means sharing a large garden, a common house, a reception room, a collective laundry room, etc. These solutions can only strengthen the social exchange.

I cite the example of the K'hutte building and its colorful balconies, located in the Brasserie eco-district in Cronenberg. It is the largest building built in self-promotion, consisting of 23 apartments on five floors. Depending on the wishes of the inhabitants and their means, the project responds to a common desire to promote sharing, benevolence and social diversity [12].

These participatory habitats revolt against the traditional form of buildings, towers, and skyscrapers of collective housing. Another example that I find revolutionary in its time is Habitat 67 in Montreal at the Cité du Havre, in Canada, designed by the architect Moshe for

Figure 5: K'hutte, Participatory housing, Strasbourg, 2015 [12].

the 1967 World's Fair [13]. The architect, only 23 years old, said that Habitat 67 is really two ideas in one. One is about prefabrication and the other is about redesigning apartment buildings in the new paradigm. He succeeded in creating a new housing typology that is both efficient and adaptable to the site. Habitat 67 pioneered the integration of two housing typologies: the suburban garden house and the economical apartment building. He explored the possibilities of prefabricated modular units to reduce housing costs and enable a new housing typology that could incorporate the qualities of a suburban home into an urban tower.

3.3 Adaptive lifestyles

Today, we live in apartments built more than 40 years ago. Since then, lifestyles have changed and so has our way of occupying space. The evolution of mores and family models as well as ecological and economic crises lead to the evolution of the habitat to follow the rhythm and adapt it to family changes such as births, aging and anticipation of a reduced income or a disability [14]. Nowadays, the pandemic has changed the purpose of buildings by transforming houses into offices or a place of education. Facing this reality, Éric Cassar "Habiter l'infini", tried to re-question the ways of living. It is based on the one hand, on past and present experiments (shared housing, participatory housing, etc.) and on the other hand, on the opportunities offered by the progress of technologies and techniques [15]. He said, "If we succeed to better manage this time layer on the space layer, we will certainly find space". Housing in infinity means reducing the intimate sphere of the apartment and adding shared spaces (either all together or one after the other). This gives the impression that we live in spaces larger than reality. The space is flexible by renting out part of the accommodation, allowing people to reserve a space via smart phones and internet applications. People are connected, the whole city is connected and thus, we are talking about "smart buildings" and "smart cities".

It is an inter-generational shared housing model. It is neither a participatory habitat nor a community habitat but a habitat where the area of the intimate sphere is reduced in favor of shared spaces managed by digital technology. This increases both the living space and its uses in order to promote social exchange between inhabitants. The modular, recyclable and

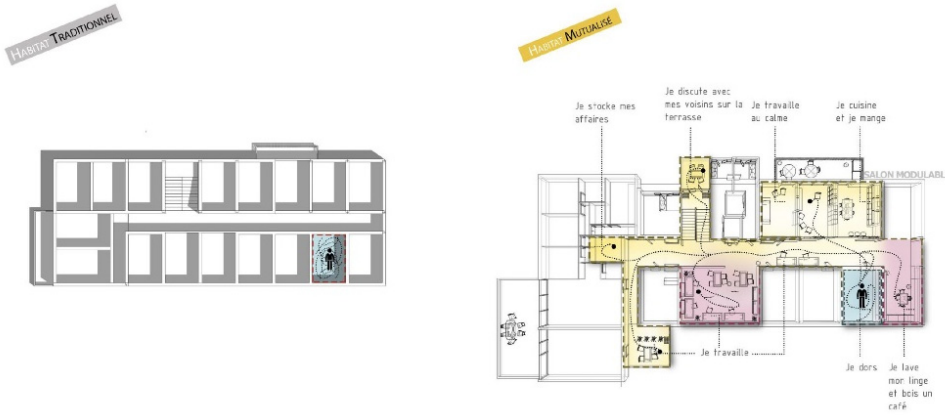

Figure 6: Living in infinity by Éric Cassar [15].

movable habitat is a solution that offers more flexibility to the space. For example, imagine the possibilities available by adding an extension and then changing the use of it or moving the wall partitions in order to make the building evolve according to the needs and to change vocation of the building over time.

4 TOWARDS AN ECOLOGICAL APPROACH TO ARCHITECTURE

Nowadays, the issues discussed are often about housing as well as neglected and non-ecological cities. This crisis must encourage public authorities and architects to build differently and to design cities differently. There is also an interest in living environments that have for too have been neglected until recent times. Due to weeks of confinement following the epidemic, this has affected the relationship between citizens and their place of residence and work, especially those who live in apartments without a terrace and without outdoor spaces.

Nowadays in Tunisia, everyone has ancestors who live in the countryside. Having a small house with landscaping and a small garden has become a dream for every citizen. Therefore, the concept of the "RubixHome" by the architect Thierry Rampillon of the CR&ON agency, "Terrace for all" brings the village to the city and integrates nature within the city [16].

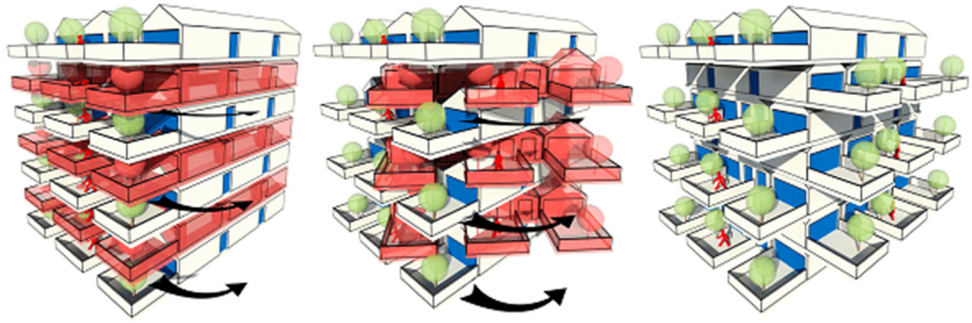

Figure 7: Rubixhome, new generation of collective housing [16].

Inspired by plants with leaves that are arranged in staggered rows to capture the sunlight, the Rubixhome concept provides buildings with terraces organized throughout the entire structure, offering 25m^2 of open air to each resident at affordable costs. The staggered organization of the terraces is created in order to superimpose large terraces over the entire height of the building and reduce the sunlight. The staggered arrangement has many benefits. First, the advantage of having a terrace on every two floors allows the sunlight to pass through. Second, the Rubixhome buildings face southeast or southwest. In summer, the sun can be a source of excessive heat, but its heat is tempered by the shade generated by the terrace above. In winter, the sunshine dives into the apartments and make it warm. Adding to this bio climatic arrangement are terraces of deciduous trees, which provide shade in summer and allow the sunshine to pass through in winter.

CR&ON Architects agency proposes a project under study "îlot B4", within the ZAC Vigny Musset in Grenoble. This project, with 37 housing units, is based on the Rubixhome concept. Each unit in the tower has a living room, kitchen, terrace, indoor–outdoor space of 50 m^2, united by a continuous floor without a threshold and a 3 m wide bay window. The arrangement of these staggered terraces offers a height of 5 m under the ceiling of the terraces. The organization of the housing is based on an economical and efficient construction system structured according to a basic plan of three circles: a vertical interior distribution, a circle of interior spaces and a circle of exterior extensions [17].

Figure 8: Îlot I B4, ZAC Vigny Musset, Grenoble [12].

In fact, a habitat that respects its environment uses the natural resources within the design process and integrates sustainable development technologies. It is necessary to take into account the location, the orientation, the architectural form, the interior design organization and the technologies in order to succeed in re-regulating the climate and living in symbiosis with nature. Plants are a climate regulator (protection against sunshine in summer and

protection against rain and wind in winter); they protect the south facades with shade and filter dust. They also protect against hot wind and oxygenate the air. Ecological housing is the main concern of housing construction for the future. It means building intelligently and ecologically, capturing natural light, using efficient insulation, controlling the temperature and utilizing landscape design. Some architects design housing using local materials while others conceive of ecological neighborhoods that respond to the needs of its inhabitants "to live, work, have fun, and move around while still respecting the environment".

This architecture is linked to nature and its components by considering the natural environment within the design process. Moreover, it allows for dialogue between human beings and the natural environment by simulating different emotions and sensations. Opacity and transparency, natural and artificial light, outdoor and indoor spaces and landscape are the fundamental components of housing towards a sustainable and eco-responsible approach.

5 CONCLUSION

Finally, through unique reflections, research projects and achievements, experts (architects, urban planners, designers, engineers, economists, promoters, sociologists and philosophers) can respond today to live tomorrow. Several solutions could be taken into account to improve the city for the future; at the habitat scale, to improve the living conditions, as well as at the urban scale. There is a need to integrate landscaping and provide new solutions for a modular, recyclable, movable architecture which is respectful of the environment with a low energy impact. The city of tomorrow must offer quality of life and involve its inhabitants within the design process, and it must be smart, connected and eco-responsible. The challenge today is the complexity of life, which means we all share different lives, different social status, different generations living under the same roof in the same city [18]. The city of the future should offer modularity to respond to the complexity of our life paths: a life where you can both live and work. A multifunctional architecture, connected to its environment, involves its inhabitants, develops social exchange, and fights against exclusion. It also integrates new technologies and new uses and provides a better service to individuals. Housing for the future should be environmentally friendly and easily accessible with a mix of uses. The same building can change its uses during the same day or the same period by adapting it to social change. The city of the future promotes social and cultural exchange and integrates technology. It is completely responsible to the environment by developing actions against the danger of climate change towards a low-carbon city. Considering these solutions will have positive effects on the user and his well-being because a valuable architectural structure can only produce a valuable citizen, even a fulfilled and united society. This architecture responds to specific context as well as the needs of daily life.

REFERENCES

[1] Simay, P., *Living in the World*, Actes Sud/ARTE edition, p. 256, 2019.
[2] Jonas, A. & Rihn, L., *Living in the World*, de la Martinière Jeunesse, p. 69, 2019.
[3] Viviane, B., *The Medina of Tunis: A City of the Arabian Nights*, Edition Gallimard: Paris, 2007.
[4] Ben Abdallah, H., *Entre-soi et repliement social ou les nouvelles formes de sociabilité, Le cas d'Ennasr II à Tunis,* pp. 89–105, 2009.
[5] Ben Ayed, A. & Turki, S., *Round Table: The Urban Quality of your Cities, Under Discussion*, Archibat No. 34: What future for our cities? p. 45, 2015.
[6] Bessaad, J., *For a New Housing Strategy*, Archibat No. 34: What future for our cities? p. 55, 2015.

[7] Hutin, C.H., *Communities at Work*, Catalog of the French Pavilion of the Venice Architecture Biennale, 320 pp., 2021.
[8] Floornature, Transformation of 530 dwellings Grand Parc Bordeaux wins EU Mies Award, 2019. https://www.floornature.com/transformation-530-dwellings-grand-parc-bordeaux-wins-eu-mie-14609/#.
[9] Hutin, C.H., The highlands by Christophe Hutin. *Architecture Review Today*, AA no. 433 – Social housing, a French exception? 2019.
[10] Fathy, H., *Building with the People*, Sindbad, Éditions Actes Sud, 305 pp., 1996.
[11] What exactly is participatory housing? France 5. www.youtube.com/watch?v= JoWurnfiheE, 2015.
[12] Parasote, B., *Participatory Housing for 20 Families*, La Maison Écologique no. 93, 2016.
[13] McIntosh, A. & Carter, J., *Habitat 67*, L'encyclopédie Canadienne, 2018.
[14] Bazin, B., *Towards Modular and Scalable Housing*, LinkedIn, 2021.
[15] Cassar, É., *Living in Infinity, New Habitat in the Digital Age*, Arkhenspaces, 2015.
[16] Rampillon, T., Rubixhome, new generation of collective housing. *UP Magazine*, 2015.
[17] Creon.archi, îlot I B4 – Zak Vingny Musset – 37 Logements à Grenoble. http://www.creon.archi/6-projets-a-la-loupe/ilot-i-b4-zac-vigny-musset-38-logements-grenoble/.
[18] Urban Revolutions: The Smart City according to Carlo Moreno, Daniel While, Véronique Pappe, Charles Ragons, Fabien Cauchi, 2019. https://www.primonialreim.fr/fr/revolutions-urbaines-la-smart-city-selon-daniel-while-episode-2.

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USING CIRCULAR ECONOMY BUSINESS MODELS AND LIFE CYCLE ASSESSMENT TO IMPROVE THE SUSTAINABILITY OF ELEVATORS

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ABSTRACT

About 55% of the world's population is currently living in cities, and an increasing level of urbanisation is expected in the future. Therefore, construction of tall buildings is increasing and, accordingly, the installation and maintenance of elevators are increasingly crucial enablers. Electric drives are one of the main components of elevators, controlling their movement, speed and torque. The lifetime of elevator drives is commonly shorter than that of the elevator, and thus, the drive needs replacing one or more times during the elevator's lifetime, contributing to environmental impacts. This work explores the potential of drive refurbishment to improve the sustainability of the elevator. The potential reduction of environmental impacts related to the use of refurbished compared to new drives was assessed via life cycle assessment (LCA). Two elevator drives, the OVF20 (Otis) and the VF22BR (Schindler), were considered for this assessment, including empirical data collection on component materials and masses. Across a range of 18 impact categories, the results showed that refurbishing an elevator drive causes 53–91% lower environmental impacts compared to the construction of a new drive, and has the potential to reduce e-waste volumes by 72–84% depending on the drive considered. Across the lifetime of a whole elevator system, electricity consumption is the main source of impacts, accounting for 63–99% of the total, while the drive itself contributes ≤27%. Nonetheless, it is possible to decrease the lifetime environmental impacts of an elevator by 1–17% by installing refurbished elevator drives. Overall, the results of this study suggest that the use of circular economy strategies can markedly improve the environmental sustainability of elevators and could be coupled with other green elevator strategies to enable more eco-friendly urbanisation.

Keywords: lifts, circularity, LCA, e-waste, environmental impacts, green elevator strategy, elevator drive.

1 INTRODUCTION

Significant increases in urban population have been reported during the past 30 years, with about 55% of the global population currently residing in cities [1], and forecasts reporting that this trend is expected to continue [2]. This rapid urbanisation has led to the construction of increasingly taller buildings to optimise land use in urban areas [3]. In this context, elevators are crucial to maintain the accessibility of tall buildings. Consequently, since 2012 the number of elevators installed worldwide has increased from about 11 million to over 18 million [4], with continued growth expected in the foreseeable future: the market is predicted to grow from its current value (US $99.30 billion) to $120–130 billion by 2029 [5], [6].

A variety of prior scientific literature on elevators has addressed performance, energy efficiency, maintenance and control, and other predominantly technical issues [3], [7]–[10]. Elevator drives are one of the main components of elevators as they control their movements, speed, position and torque. When these drives malfunction, they are typically replaced with new ones, and the defective drives are disposed as e-waste. Moreover, the lifespan of an elevator drive, which varies depending on the drive model, is commonly shorter than that of the elevator itself (the latter being at least 20–30 years) [8], [11]. Thus, it is possible that the

drive will be substituted multiple times during the lifespan of the elevator. Consequently, refurbishing malfunctioning elevator drives could greatly reduce the amount of e-waste produced. However, to the authors' knowledge, there are no prior publications investigating the environmental sustainability implications of such a circular strategy in the elevator sector.

Accordingly, this study uses life cycle assessment to investigate the impact and footprint of elevator drive refurbishment according to the procedures developed by a UK-based company – Northern Drives and Controls (NDC) Ltd – and compare this to the standard industry practice of installing new replacement drives. Two different commercial elevator drives, namely the OVF20 (Otis) and the VF22BR (Schindler), are used as exemplars. In order to provide a broader context to the impacts of an elevator drive, its environmental sustainability is also assessed as a part of the whole elevator system. The aim of this assessment is to determine the potential benefits of applying waste management options which adhere to circular economy principles for elevator drives. More broadly, this study aims to provide further foundations for circular business models in sectors dealing with electronics and/or urban infrastructure.

2 METHODOLOGY

The life cycle assessment (LCA) models were developed according to the ISO 14040/44 guidelines [12], [13], and thus, the goal and scope of the study, inventory analysis, impact assessment and interpretation are described below. All assessments followed the attributional approach and GaBi 10.5 software [14] was used for system modelling.

2.1 Goal and scope

The main goal of this study was to assess the environmental impacts of refurbishing elevator drives in comparison to the installation of new ones. To account for variability between drives, two different models were chosen to be analysed side by side: Otis OVF20 and Schindler VF22BR. These specific models were chosen based on their prevalence in the market, as determined by the direct experience of project partner NDC Ltd. The purpose of this study was to allow the identification of benefits and drawbacks of refurbished drives as well as improvement opportunities. A secondary goal was to assess the environmental sustainability of the drive in the context of the whole elevator system to determine the relevance of the elevator drive to the impacts of the elevator.

The functional unit (FU) for the elevator drive is "refurbishing or production of a drive unit", while for the LCA of the elevator system the functional unit is "25 years of operation of the elevator", which represents the average lifetime of an elevator [8], [11], [15].

A cradle-to-grave approach was considered for the production/refurbishing of the elevator drive (Fig. 1). The system boundaries for the refurbishing process include the drive's transportation to the repair site, testing to assess which components need to be replaced, repairing, a second set of tests to assess if the refurbished drive is performing as expected, disposal of e-wastes produced and transport of the refurbished drive to the elevator site. A simpler system was considered for the assembly of a new drive, which included the assembly of a new drive, its transportation to the elevator site and the disposal of the broken drive. For the LCA of the elevator system the lifetime electricity consumption of the elevator was also accounted for.

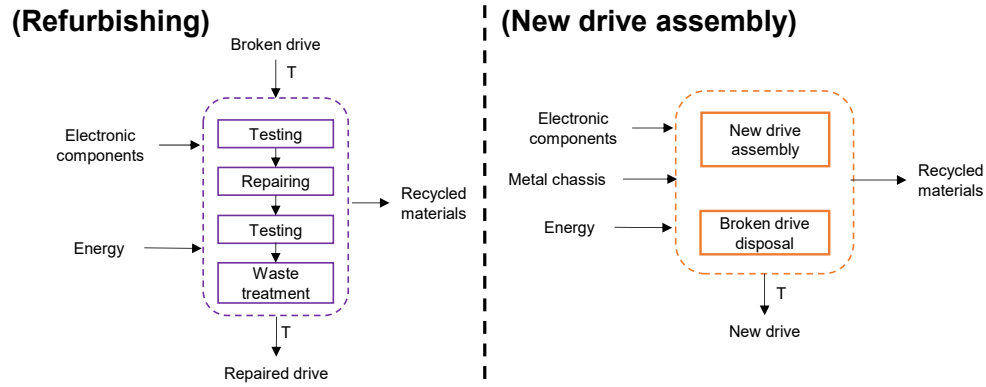


Figure 1: System boundaries for the refurbishing of an elevator drive and for the assembly of a new drive. T = transport.

2.2 Inventory data

Tables 1 and 2 report inventory data for the OVF20 and VF22BR drive respectively. Inventory data for the refurbishing processes were provided directly by the project partners NDC Ltd, while balance of materials for the drives themselves were estimated empirically by disassembling each drive and weighing and identifying its components. This was performed at the University of Manchester Power Conversion Laboratory where each assessed drive was methodically taken apart following commercial guidelines and the required characteristics of its subassemblies evaluated. Background data for materials and energy were obtained from Ecoinvent 3.7 [16], assuming that the refurbishing process is based in the UK, while the production of new drives depends on the location of the producer company. The authors note that some of the inventory data on electronics in the Ecoinvent database originally dates from the 2000s and may require updating to accurately reflect current electronics manufacture. However, in the absence of newer, robust data, it remains the most reliable source.

For the transportation of new and refurbished drives, it was assumed that 60% of the broken drives would come from the UK, 30% from Europe and 10% from the US, based on real market data from NDC Ltd. For the refurbished drive it was assumed that drives from the UK could be transported to the refurbishment site by road, while flights would be necessary for other locations based on the quick turnaround time expected by elevator owners. Return trips to the elevator site were also accounted for. Bulk transportation by shipping to warehouses located in different countries was considered for new drives, with short haul flights or road transportation assumed to transport the drives from the warehouse to the elevator site. A transportation distance of 50 km to the disposal site was considered for all waste treatment. The percentages of different materials recycled or landfilled are estimated according to country-specific statistical data and relevant regulations [17]–[21].

For the estimation of the elevator's electricity consumption an energy calculator provided by Thyssenkrupp was used [22]. For this case study, it was assumed that the drive unit was part of a geared office elevator of capacity six people, serving a six-floor building and operating at a speed of 0.8 meter per second. Accordingly, an electricity consumption of

Table 1: Inventory data for the production and refurbishing of the OVF20 drive.

Item[a]	OVF20			
	New	Refurbished	Unit per drive	Comment
Chassis	14.1	–	kg	Mainly aluminium
Printed circuit board (PCB)[b]	0.15	–	m^2	Includes four PCBs
Transformer	409	–	g	Includes one transformer mounted on a PCB
Resistor	201	–	g	Includes 19 resistors mounted on PCBs
Capacitor	1.1	1.0	kg	Includes electrolytic and film capacitors mounted on PCBs. An average of 33 out of 34 capacitors are replaced during refurbishment
Power line filter[c]	2.8	–	kg	Includes 1.1 kg of chassis and 1.7 kg of electronic components
IGBT module	1.5	1.0	g	Includes four IGBT modules. Three of the four modules are substituted during refurbishment
Optocoupler	5.6	–	g	Includes seven optocouplers mounted on PCBs
Cooling fan[c]	1.9	–	kg	A single metal fan is used for cooling
Contactor	1.6	–	kg	
Cable block	745	–	g	
Current transducer[c]	36	36	g	Includes two transducers mounted on PCBs
Transient surge absorber	3.9	–	g	Includes two surge absorbers mounted on PCBs
Gas discharge tube	2.7	–	g	
Fuse	4.6	4.6	g	
Testing electricity	–	0.44	kWh	
Elevator lifetime electricity consumption	89.9	89.9	MWh	
Transport	155	65.4	tkm	Transportation distances based on locations of Otis and NDC headquarters

[a] Life cycle inventory data sourced from Ecoinvent 3.7 [16]; [b] The PCB production process is based on literature data [23]; [c] Background process from Ecoinvent was modified to describe the specific component.

Table 2: Inventory data for the production and refurbishing of the VF22BR drive.

Item[a]	VF22BR			
	New	Refurbished	Unit per drive	Comment
Chassis	11.6	–	kg	Mainly aluminium
PCB[b]	462	–	cm^2	Includes two PCBs
Transformer	4.1	–	kg	Includes two transformers in the chassis and two smaller transformers mounted on PCBs
Resistor	888	–	g	Includes a resistor in the chassis and six smaller resistors mounted on PCBs
Capacitor	871	871	g	Includes electrolytic and metal film capacitors mounted on PCBs
Power line filter[c]	1.1	–	kg	
IGBT module	277	277	g	Includes two IGBT modules
Power supply	240	240	g	
Cooling fan	345	345	g	Three plastic fans are used for cooling
Contactor	337	337	g	
Cable block	17	–	g	
Safety relay	35	35	g	
Testing electricity	–	0.278	kWh	
Elevator lifetime electricity consumption	89.9	89.9	MWh	
Transport	62.4	67.6	tkm	Transportation distances based on locations of Schindler and NDC headquarters

[a] Life cycle inventory data sourced from Ecoinvent 3.7 [16]; [b] The PCB production process is based on literature data [23]; [c] Background process from Ecoinvent was modified to describe the specific component.

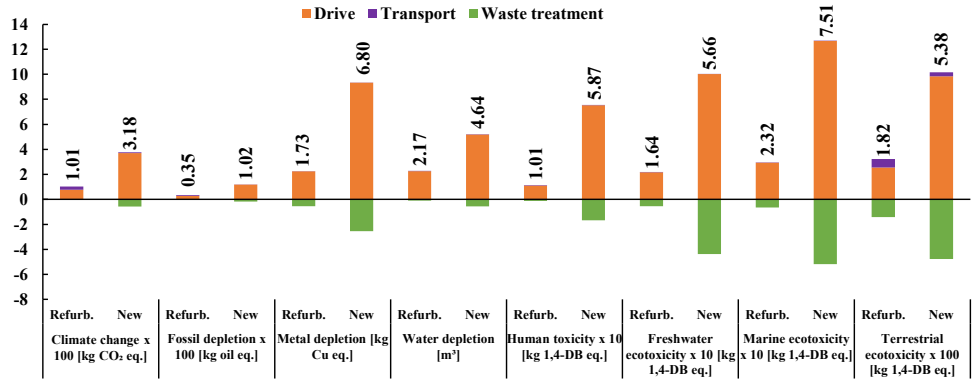
89.9 MWh over 25 years of operation was estimated. The UK electricity mix was adopted for this case study, using the latest version (circa 2017) available in Ecoinvent: 39% natural gas, 22% nuclear, 19% renewables (wind, solar, hydro), 8% imports, 6% biomass and 6% coal. Given the continued greening of electricity supply, the use of a recent mix is conservative. Note that electricity consumption from the exhaust fan and from the cab lighting have been excluded from this total as these are independent from the elevator drive and are unlikely to contribute significantly to the total. The rated power consumption of the two drives under investigation during operation is 9 and 2 kW for the OVF20 and VF22BR drive, respectively.

2.3 Impact assessment

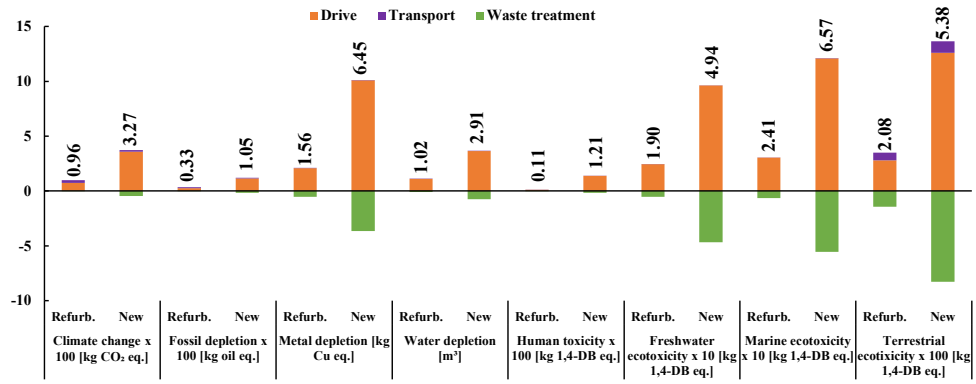
The environmental impacts were estimated using the ReCiPe 2016 V1.1 impact assessment method at the mid-point level, following the hierarchist approach [24]. Seven impact categories, including climate change, depletion- and toxicity-based categories, were selected for this assessment from the 18 impact categories of the ReCiPe method due to their relevance to the assessment and their representativeness of the trends observed.

3 RESULTS AND DISCUSSION

Fig. 2 reports the life cycle impacts estimated for the OVF20 and VF22BR drives. Note that, for each drive, the refurbished and new cases are compared on a 1:1 ratio. This is conservative because the refurbishment process addresses common points of failure for each drive model, meaning that a refurbished drive may in fact last longer than a new one, leading to a smaller number of refurbished drives being required over the lifespan of the elevator compared to new drives.



(a)



(b)

Figure 2: Life cycle environmental impacts of new and refurbished drives. (a) OVF20; and (b) VF22BR. All impacts are expressed per drive produced or refurbished. Some impacts have been scaled to fit. To obtain the original values, multiply with the factor on the x-axis, where relevant.

Fig. 2(a) reports the life cycle impacts of the OVF20 drive, demonstrating that refurbishment causes lower environmental impacts (by 53–83%) than the production of a new drive. In both cases, impacts are mainly caused by the materials and energy used in the drive's production or refurbishing (66–90% and 55–95% of the total impact, respectively).

In the case of the refurbished drive, transport shows significant contributions to climate change (23%), fossil depletion (22%) and terrestrial ecotoxicity (15%), while it emerged as a minor contributor to human toxicity (2%), and a negligible contributor (<1%) to other impacts. On the contrary, transport emerged as a minor contributor to the environmental impacts of the new drive, accounting for ≤2% in all categories considered. The larger contribution of transport to the impacts of the refurbished drive is because transportation to the refurbishment site and a return trip to the elevator site was included, with longer hauls being performed by flight; in contrast, one-way transport and different assumptions were assumed for the new drive (Section 2.2).

Recycled materials were credited to the system as part of the waste treatment, subsequently decreasing the environmental impacts of the refurbished drive by 2–30%. The recycling credits applied to the new drive were more substantial, lowering the impacts by 10–32%, mainly because of the recycling of the aluminium chassis (which would not be disposed of during refurbishment). Although more significant credits are attributed to the waste treatment of the new drive, it should be borne in mind that more wastes are produced, including 17.1 kg of metals and 7.6 kg of e-waste, in comparison to the refurbished drive (2.1 kg of e-waste) which could result in larger costs for waste treatment.

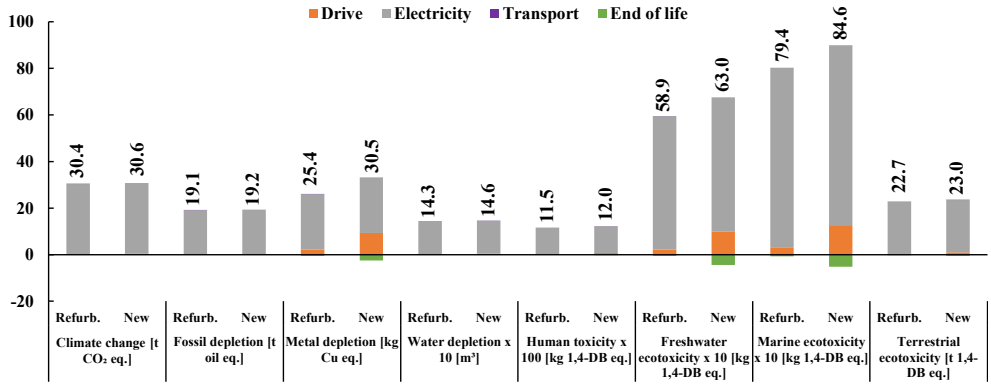
Similar trends were found for the VF22BR drive, with refurbishment resulting in 61–91% lower environmental impacts than those of a new drive (Fig. 2(b)). Drive refurbishing (57–91%) or production (57–89%) emerged as the main contributors to the impacts in both cases, while transport shows significant contribution to the impacts of the refurbished drive on climate change (25%), fossil depletion (23%) and terrestrial ecotoxicity (14%), but negligible contributions to other categories. For the new drive, transport accounts for ≤5% of the impacts. Credits from the recovery of recycled materials allowed a reduction in impacts of both refurbished (2–29%) and new drives (10–38%). The greater credits observed for the new drive are due to the larger mass of waste produced by its disposal (12.1 kg of metal components and 13.4 kg of e-wastes per drive) compared to the disposal of refurbished components (2.1 kg of e-wastes per drive). Accordingly, the refurbishing of VF22BR drives enables a 92% reduction in the total amount of waste produced and an 84% reduction in the amount of e-waste.

Overall, this analysis clearly shows the potential benefits of drive refurbishment in comparison to replacement with a new drive. However, the environmental impacts of the refurbished drive could be reduced further by optimising the logistics to reduce transportation distances and avoid, where possible, air freight. To this end the authors note that NDC is currently setting up service centres in various key countries, such as the USA, Germany and Spain, which should enable logistics streamlining and therefore impact reduction. Ultimately, a robust comparison of real-world transportation differences between new and refurbished drives is difficult to establish due to differing business practices, market exposures and other variables across the sector.

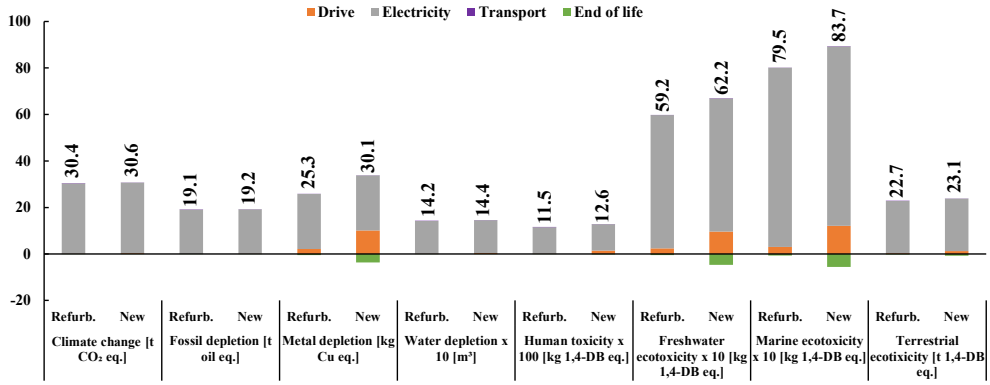
3.1 Assessment of the elevator system

Fig. 3 reports the environmental impacts of the whole elevator system and shows that the lifetime electricity consumption of the elevator is the main source of impacts for refurbished (89–99%) and new drives (63–99%), for both drive models. Larger contributions are

estimated for the new drive (1–27%) compared to a refurbished one, but in both cases the drive itself shows negligible contributions to climate change, fossil depletion and water depletion, as well as ≤8% to the other impacts. This is because, based on available data, there is no reason to expect any difference in the electricity consumption of elevators utilising new versus refurbished drive, and therefore electricity is similarly dominant in both cases. Overall, this analysis shows that utilising refurbished drives has the potential to reduce the life cycle impacts of the elevator by 1–17% for the OVF20 and by 1–16% for the VF22BR.



(a)



(b)

Figure 3: Life cycle environmental impacts of an elevator using new and refurbished drives. (a) OVF20; and (b) VF22BR. All impacts are expressed per 25 years operation of the elevator. Some impacts have been scaled to fit. To obtain the original values, multiply with the factor on the x-axis, where relevant.

It should be noted that, during the lifespan of an elevator system, the supplied electricity mix is likely to become lower carbon with a greater contribution from renewables. Consequently, the relative contribution of electricity to the environmental impacts is likely to decrease over time, meaning the relative importance of the drive and other hardware will increase along with the benefits derivable from refurbishment.

4 CONCLUSIONS

This study assessed the potential cradle-to-grave environmental benefits of refurbishing elevator drives as a circular economy strategy, contrasting with the conventional practice of replacement with a new drive unit. In a one-to-one comparison between drives, the results show that refurbished drives have the potential to reduce the total amount of waste produced by 91–92% and the amount of e-waste by 72–84% depending on the drive model. It was also observed that the reduction in material usage achievable via the refurbishment strategy enables a decrease in the drive's environmental impacts of 53–91% compared to the production of a new drive. When considering the whole elevator system it was found that electricity use is the main contributor to the impacts (63–99%). However, elevators using refurbished drives have the potential to reduce their life cycle impacts by ≤17% due to the reduced mass of materials needed. These findings are conservative as, depending on the drive model and refurbishment process, the refurbished drive might have a longer lifespan than a new drive due to the elimination of common failure points. Consequently the above results indicate the minimum likely benefits of a repair-oriented circular business model.

Overall, refurbishment offers the potential to significantly reduce the demand for materials and the generation of waste during the lifetime of elevators, improving their environmental sustainability significantly. Future research should address the optimisation of transport logistics for elevator drives, and the application of circular models to emerging drive technologies as well as other components of elevator systems.

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REFERENCES

[1] The World Bank, Urban development overview. https://www.worldbank.org/en/topic/urbandevelopment/overview#1. Accessed on: Jun. 2022.
[2] Seto, K.C., Guneralp, B. & Hutyra, L.R., Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proc. Natl Acad. Sci. USA*, **109**, pp. 16083–16088, 2012.
[3] Dalala, Z., Alwahsh, T. & Saadeh, O., Energy recovery control in elevators with automatic rescue application. *Journal of Energy Storage*, **43**, 2021.
[4] Statista, Number of elevators and escalators in operation from 2012 to 2021. https://www.statista.com/statistics/1201896/elevators-escalators-operation-worldwide/. Accessed on: Jun. 2022.
[5] Data Bridge Market Research, Global elevator market: Industry trends and forecast to 2029.
[6] Global Market Insights, Elevator market size.
[7] Niu, D., Guo, L., Zhao, W. & Li, H., Operation performance evaluation of elevators based on condition monitoring and combination weighting method. *Measurement*, **194**, 2022.
[8] Zhang, X. & Zubair, M.U., Extending the useful life of elevators through appropriate maintenance strategies. *Journal of Building Engineering*, **51**, 2022.
[9] Jiang, X.-Y., Huang, X.-C., Huang, J.-P. & Tong, Y.-F., Real-time intelligent elevator monitoring and diagnosis: Case studies and solutions with applications using artificial intelligence. *Computers and Electrical Engineering*, **100**, 2022.

[10] Niu, D., Guo, L., Bi, X. & Wen, D., Preventive maintenance period decision for elevator parts based on multi-objective optimization method. *Journal of Building Engineering*, **44**, 2021.
[11] Junnila, S., Horvath, A. & Guggemos, A.A., Life-cycle assessment of office buildings in Europe and the United States. *Journal of Infrastructure Systems*, **12**, pp. 10–17, 2006.
[12] ISO 14040/44, Environmental Management – Life Cycle Assessment – Principles and Framework, Geneva, 2006.
[13] ISO 14040/44, Environmental Management – Life Cycle Assessment – Requirements and Guidelines, Geneva, 2006.
[14] Thinkstep, GaBi. https://www.thinkstep.com/.
[15] Corner, R., Project correspondence, 2022.
[16] Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E. & Weidema, B., The Ecoinvent database version 3 (part I): Overview and methodology. *The International Journal of Life Cycle Assessment*, **21**, pp. 1218–1230, 2016.
[17] EPA, AP 42, Fifth Edition, Volume I Chapter 12.8 Secondary Aluminum Operations. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-fifth-edition-volume-i-chapter-12-metallurgical-0. Accessed on: Jun. 2022.
[18] ALFED, Aluminium recycling. https://www.alfed.org.uk/files/Fact%20sheets/5-aluminium-recycling.pdf. Accessed on: Jun. 2022.
[19] IAI, Aluminium RECYCLING FACTSHEET. https://international-aluminium.org/resource/aluminium-recycling-fact-sheet/. Accessed on: Jun. 2022.
[20] Statista, Recycling rate of electrical and electronic waste in the United Kingdom (UK) from 2010 to 2018. https://www.statista.com/statistics/632826/e-waste-recycling-uk/. Accessed on: Jun. 2022.
[21] EU, Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) Text with EEA relevance. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0019. Accessed on: Jun. 2022.
[22] Energy calculator. https://design.na.tkelevator.com/tools/energy-calculator. Accessed on: Jun. 2022.
[23] Ozkan, E., Elginoz, N. & Germirli Babuna, F., Life cycle assessment of a printed circuit board manufacturing plant in Turkey. *Environ. Sci. Pollut. Res. Int.*, **25**, pp. 26801–26808, 2018.
[24] Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F., Stam, G., Vieira, M.D.M., Hollander, A., Zijp, M. & van Zelm, R., ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and endpoint level – Report I: Characterization. https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf. Accessed on: Jun. 2022.

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Urban and Maritime Transport XXVIII

Edited by: ***G. PASSERINI****, Marche Polytechnic University, Italy and* ***S. RICCI****, University of Rome "La Sapienza", Italy*

Containing papers presented at the 28th International Conference on Urban and Maritime Transport and the Environment, this volume covers two, apparently, parallel topics which meet in the transport and environmental management of coastal cities, both being affected positively and negatively by landside and seaside traffic.

The continuing requirement for better urban transport systems and the need for a healthier environment creates a fertile environment for original ideas, innovative approaches and applications of advanced technologies, their tests and evaluations in practice. Moreover, there is a growing need for integration with IT systems and applications to improve safety and efficiency.

Maritime Transport is highly interconnected with rail, road and air services, as well as inland waterways. Each of these must therefore operate complimentary of one another to maximise efficiency and respond rapidly to variable economic and political contingencies.

The variety of topics covered by the included research works reflects the complex interaction of transport systems with their environment and the need to establish integrated strategies. The shared aim is to arrive at optimal socio-economic solutions while reducing the negative environmental impacts of transportation systems typically by interdisciplinary approaches. Therefore, a focus is placed on multidisciplinary research and development, as well as operational experiences.

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