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The Soil Project of The Cycle Network as A Contribution to Urban Resilience

Antonio Alberto Clemente* and Angelica Nanni

Department of Architecture, University "G. d'Annunzio", Italy

***Corresponding author:** Antonio Alberto Clemente, University "G. d'Annunzio" - Department of Architecture, Viale Piandaro 42, 65127 Pescara, Italy. Email: antonio.clemente@unich.it*

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Abstract

In Italy and, even more, in the Mid Adriatic Region of Abruzzo, there is a separation between the cycle network and the management of rainwater resulting from extreme atmospheric events. The cycle network is framed as a contribution to slow mobility. Urban flooding is treated as a continuing emergency. From the perspective of sustainable development and urban resilience this separation has a very negative impact. The goal is to overcome separateness. And imagine the cycle network as a soil project that, in addition to supporting the transit of bicycles, is able to contribute to a better collection and management of rainwater as an alternative to the sewer system. The hypothesis of the cycle network as a soil project obliges us to broaden our gaze to those cities that have transformed water from an agent that generates dangerous conditions, into a strategic resource. Boston, San Rafael, Zwolle Enschede, Copenhagen and Philadelphia went in this direction. Methodologically, the projects and intervention programs of the cities will be compared with reference to three kinds of interdependent spaces. The network space (reserved for transit) and the materials used to build it (porous asphalt, underground channels for the flow of water). The space associated to the network with the Green Stormwater Infrastructures that contribute to increase drainage. The context space crossed by the cycle network and the relationships it establishes with the open space of the city. The comparison aims to bring out some useful lines of action to guide the actions of the urban plan in Italy and, even more, in the Mid Adriatic Region of Abruzzo. The general idea underpinning this paper is thinking about the cycle network as the infrastructural part of a larger soil project capable of triggering processes of sustainable development and urban resilience.

1. Introduction

In Italy there are two phenomena that, in recent years, have taken on an ever-greater urban importance. The first concerns urban flooding, especially those deriving from extreme atmospheric events, which is constantly increasing, both in terms of frequency and intensity [1]. This condition derives mainly from three closely connected factors: the excessive urbanization of the cities, the consequent waterproofing of the soil [2], which is associated with an inadequate sewage system [3] to deal with the stress phenomena deriving from urban flooding [4]. Emblematic is the situation of Mid Adriatic Region of Abruzzo where the coast "from above offers itself as an undifferentiated segment of the larger agglomeration that borders the entire western Adriatic area" [5].

These floods are totally unsustainable. From the environmental point of view, because of the maritime and fluvial pollution deriving from the flowing of surface waters in which, not only rain, but also the return flow of the sewage system converge. From an economic point of view, due to the damages to infrastructures, cultural heritage, residential fabric and production areas. Socially, for the risks to which the population is subjected.

The other phenomenon concerns cycling. There is clear evidence of the exponential increase in the volume of business linked to the bike economy [6] and the employment growth that the sector has shown with reference to both the production of bicycles and in the use of the labor required for the realization of the new cycle network [7]. Alongside these economic and social aspects, awareness of the multiple environmental benefits deriving from the use of the bicycle as a means of transport is becoming more and more consolidated: reduction of noise and atmospheric pollution, less production of fine dust, reduction of emissions of CO2, lower incidence of cardiovascular problems etc.

However, flooding and urban cycling are perceived as separate phenomena, unrelated and devoid of ties. On the one hand, urban floods continue to be perceived as a periodic emergency to which, from time to time, a response can be given to bring the situation back to normal in the shortest possible time. An answer that comes, often, thanks to the intervention of the Fire Brigade and Civil Protection with an increase, not negligible, on the municipal budget. And, above all, without a perspective of resolution to the problem.

On the other hand, the cycle network is seen as a contribution to sustainable mobility [8]. The cycle network is still too tied to the quantitative perspective linked to the kilometers of routes completed, to issues such as technical functionality, safety and continuity of the route, horizontal and vertical signs, and intermodality [9].

The separation between urban flooding and cycling, of course, is not accidental. The reasons are many. One of the most important is the Italian legislative framework.

2. Sector legislative framework

The current Italian legislation does not contemplate the possibility of an interdependence between the cycle path and the management and collection of water. The Traffic Laws (*Codice della strada*, Dlgs 285/92), its Implementing Regulation, (*Regolamento attuativo*, DPR 495/92), the Main criteria and design standards of cycle paths (*Principali criteri e standard progettuali delle piste ciclabili*, Circolare Ministero delle aree urbane 432/93), define the types of tracks, the dimensional and plano-altimetric characteristics of the route, its intersections with ordinary roads, project speed and the requirements of horizontal and vertical signs.

The Regulation laying down rules for the definition of the technical characteristics of cycle paths (*Regolamento recante norme per la definizione delle caratteristiche tecniche delle piste ciclabili*, DM 557/99) defines cycle routes in descending order with respect to the safety they offer for cycling users, such as: cycle paths in their lane; cycle lanes on reserved lanes; mixed pedestrian and cycle paths; mixed cycling and vehicular routes. The purpose of the decree is to promote and encourage a high degree of cycling and pedestrian mobility, an alternative to the use of motor vehicles in urban areas; aim at the attractiveness, continuity and recognizability of the cycle route; assess the profitability of the investment with reference to real and potential users and in relation to the objective of reducing the risk of accidents and the levels of air and noise pollution; verify the objective feasibility and the actual use of cycle routes by users. And with regards to surface water drainage there are only two hints.

The first is in art. 8, which states that a cross slope of 2% is sufficient, with reference to road paving with a bituminous conglomerate wear layer that favors the discharge in the existing sewerage network.

The other in art. 12 which clarifies how on the cycle paths the presence of grids for the collection of water is not allowed with main elements parallel to the axis of the tracks themselves, nor with transverse elements such as to cause difficulties for transit for cyclists.

There is nothing more in the Abruzzo Region Law *n. 8 of March 25, 2013. Interventi per favorire lo sviluppo della mobilità ciclistica* (Interventions to promote the development of cycling) outlines the strategic objectives for urban bicycle mobility. Four are the main ones: increasing the existing network of cycling lanes (privileging the creation of a network), improving safety, including the introduction of specific signage and the connection with the system of public mobility.

Nor is it possible to find anything on this subject in the Provisions for the development of bicycle mobility and the creation of the national cycling network (*Disposizioni per lo sviluppo della mobilità in bicicletta e la realizzazione della rete nazionale di percorribilità ciclistica*, L. 2/2018): art. 6 provides for the preparation of the *Biciplan* as sector plans of sustainable mobility urban plans.

Just as there is no mention in the Guidelines for the preparation and implementation of the "Biciplan" (*Linee guida per la redazione e l'attuazione del "Biciplan"*, 2019), nor is there any in the Experimental guidelines for the development of cycle mobility (*Linee Guida sperimentali per lo sviluppo della mobilità ciclabile*, 2020), both written by the Ministry of Infrastructure and Transport.

3. Biciplan

Italian Biciplans reflect sector legislation. Nor could it be otherwise. And they leave out a multitude of relevant issues such as urban flooding. To understand this, it is sufficient to compare the cycling mobility plans, approved after Law 2/2018. Five cities are examined: Padua, Trieste (Fig. 1), Genoa, Pasiano di Pordenone (Fig. 2) and Pescara (Fig. 3). Their common feature is that they are subject to extreme weather events, according to the data of the National City-climate Observatory of Legambiente [10].

It is important to underline that in none of the Biciplans attention has been paid to one of the main goals enshrined in Law 2/2018 and the subsequent 2019 and 2020 Guidelines: the reduction of the negative effects of mobility in relation to land consumption. Furthermore, in terms of innovation and experimentation, only two initiatives are worth mentioning. In Genoa, funding of €10,000 was provided for tactical urban planning experiments aimed at raising public awareness. Pasiano di Pordenone is the only case in which the Biciplan hints at the will to protect the natural and environmental heritage; however, this intention is translated into a generic wish not to alter the existing landscape balance by providing for the use of draining surfaces where possible, according to the indications contained in the Green Public Procurement.

In such a regulatory context, the issue of urban flooding has no place.

The Biciplan of Pescara is an emblematic case of the Mid Adriatic Region of Abruzzo. In recent years, the phenomenon of cycling has been widespread. In Pescara alone, around 50 km of cycle paths have been realized. A constant expansion that has allowed the city to win the Urban Award 2019 and to confirm itself, for the fifth consecutive year, as a «cycle-friendly municipality» [11]. Various projects have contributed to these results since 2015: The Pesos Project whose name derives from *PEscara SOStenibile* concerns the National experimental programme of sustainable home-school and home-work mobility (*Programma sperimentale nazionale di mobilità sostenibile casa-scuola e casa-lavoro*, Ministero dell'Ambiente e della Tutela del Territorio e del Mare L. 221/2015); Bicycles on the net (*Bici in rete*): the project aimed at the connection and reunification of existing cycle paths in the municipal area [12] and the Urban Plan for Sustainable Mobility (*Piano Urbano della Mobilità Sostenibile*) was adopted by the Municipality of Pescara in May 2017, it was subsequently partially revised, followed by a new adoption in January 2021 [13].

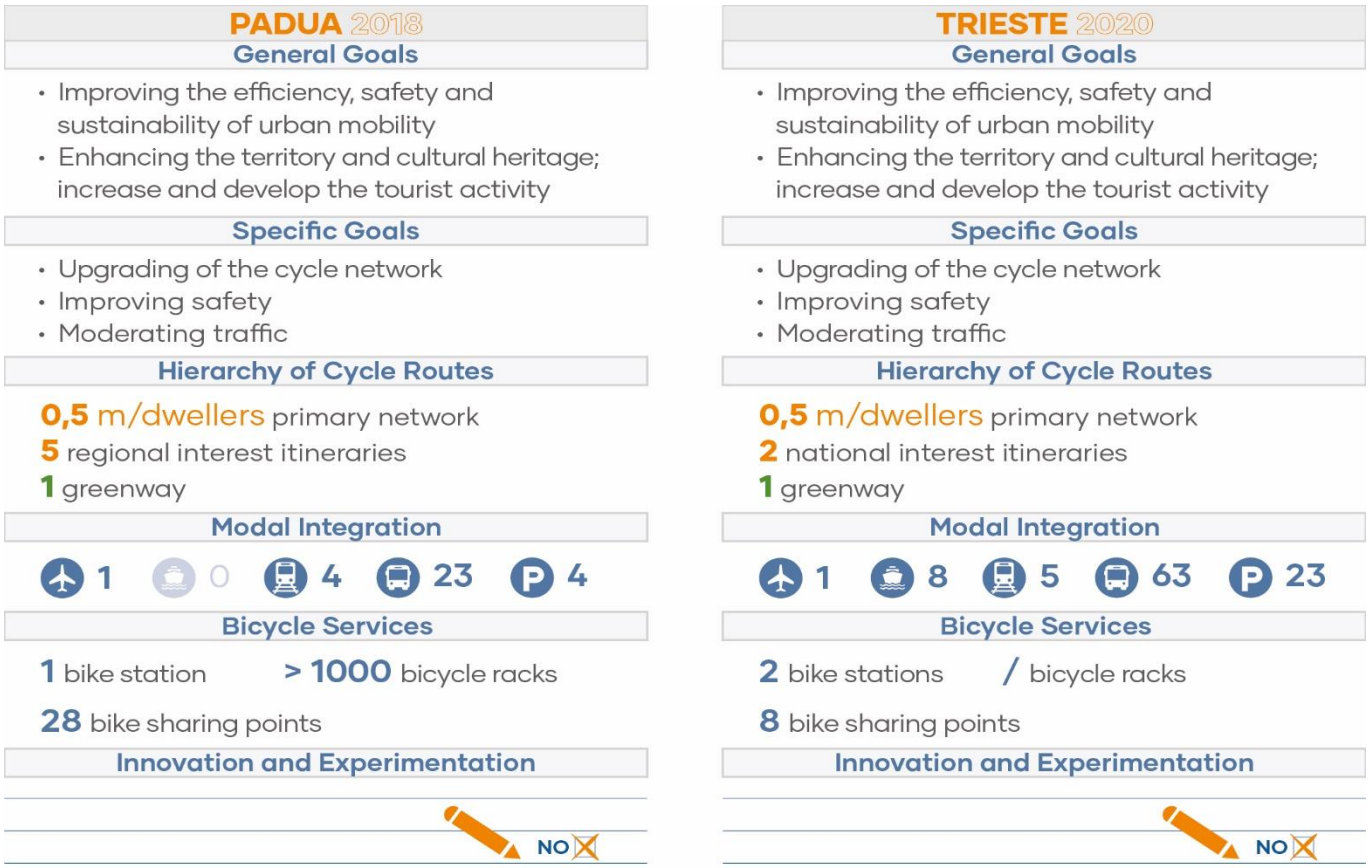

Figure 1: The main characteristics of the Biciplan of Padua and Trieste. *Original drawing by arch. Angelica Nanni.*

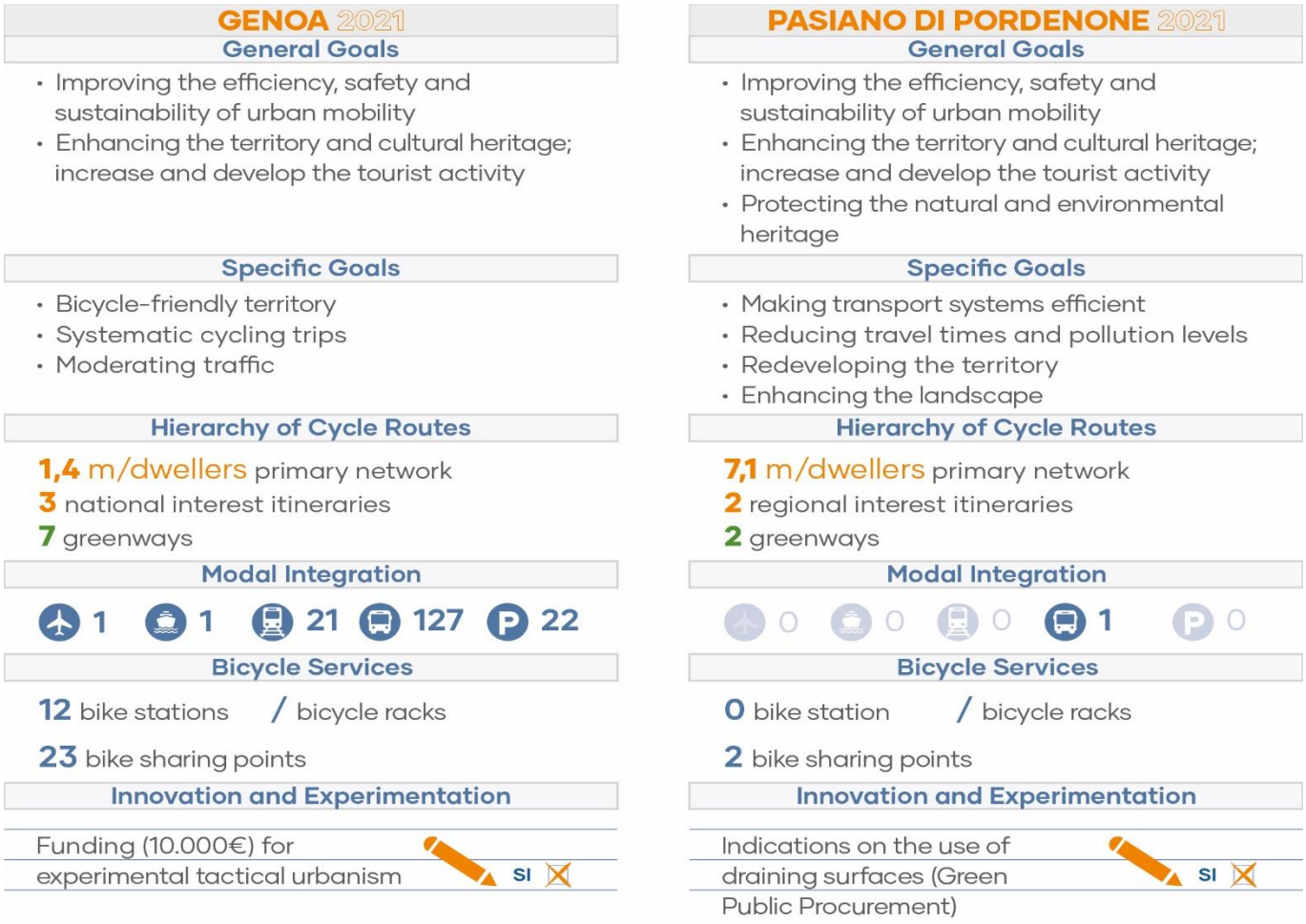

Figure 2: The main characteristics of the Biciplan of Genoa and P. Pordenone. *Original drawing by arch. Angelica Nanni.*

An exponential growth that makes it possible to say that much has been achieved. But just as clearly, it must be said that much remains to be done, especially on the environmental front, with particular reference to the collection and management of rainwater from extreme weather phenomena. The Pescara Biciplan is, like all the others, a sector plan. The main lines of action are the physical separation of paths along the main vehicular traffic ways, the creation of cycle lanes on the secondary roads, the continuity of slow mobility routes, the definition of environmental islands, of 30 zones and of safe routes to schools, the provision of bike stations near the main intermodal nodes and the most important public facilities. These are all necessary lines of action to ensure the development of slow mobility, but which say nothing about the fact that «the most frequent problem in Pescara concerns flooding due to heavy rains that almost paralyze the entire city, often causing problems in lower floors of public and private buildings and making it difficult for citizens to move around and use public facilities» [14].

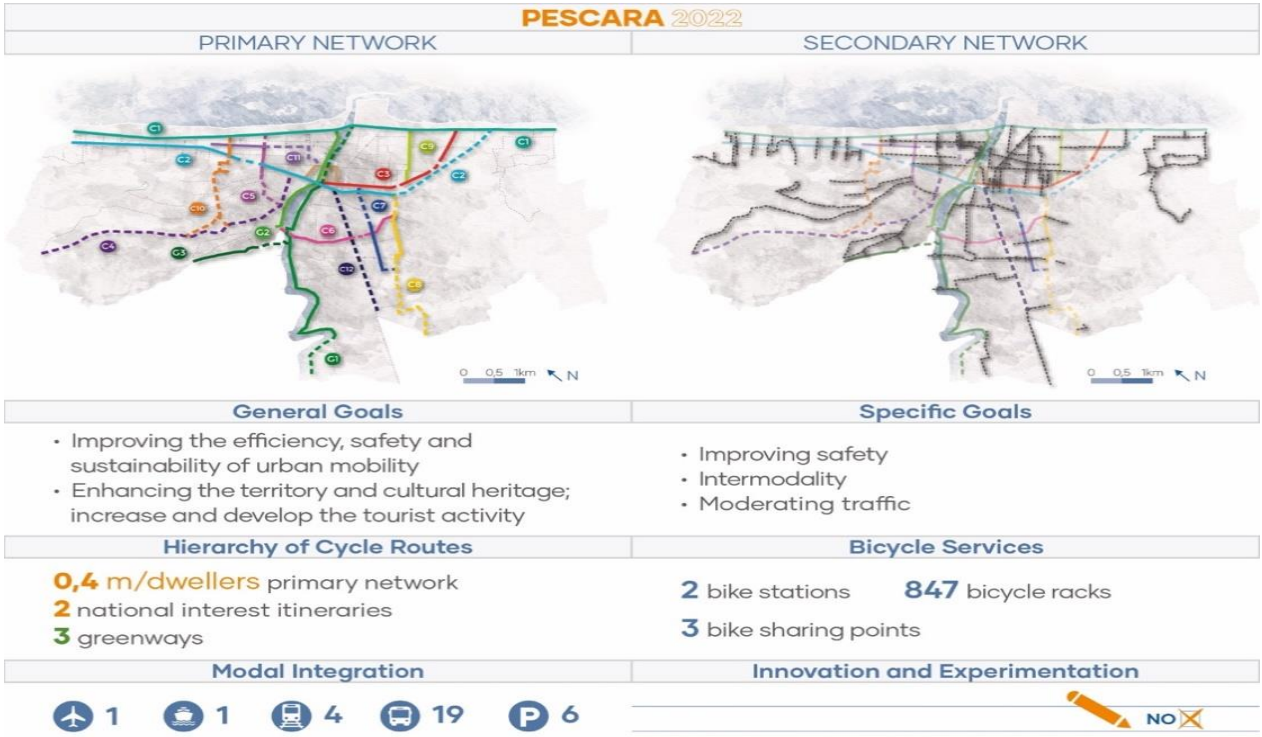

Figure 3: The main characteristics of the Biciplan of Pescara. *Original drawing by arch. Angelica Nanni.*

4. Case studies

This examination of sector legislation and its application in some Italian cities, show that the cycle network not only does not contribute to counteract urban flooding but, even, facilitates it. The cycle network is a work of waterproofing the territory. And considering that in 2017, the length of cycle paths in the provincial capitals is 4,541 km, with a growth (2011-2017) of 4.1% per year [15]; a trend that also continued in the following years [16]. It is immediately obvious that this is a significant quantity of waterproofed soil.

From the point of view of the contribution to sustainable development there is a paradoxical situation: if the economic and social pillars are perfectly verified, as mentioned in the introduction, the environmental one, on the other hand, is only partly verified due to a pervasive use of waterproofing materials that could almost always be avoided, especially in the case of bicycle lanes on own premises.

Furthermore, a mono-functionality emerges aimed at guaranteeing the movement from one place to another, in which the network space is, exclusively, the support for cycling traffic.

It is necessary to change perspective. And imagine the cycle network as an infrastructure that contributes to urban resilience, through a project in which the soil is no longer just the support for the transit of bicycles.

Resilience is defined in this paper as «the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management» [17]. It is a context in which the soil of cycle path must have its own thickness capable of improving the collection and management of rainwater, this, as an alternative to the sewage system.

It is evident that such a hypothesis of work has no ambition to be a resolutive one. Rather, it intends to delimit the field of investigation in the context of a topic of great importance. To counteract the negative effects deriving from urban flooding, urban planning must transform water from an agent generating dangerous conditions, into a strategic resource for rethinking ecological regeneration [18]. To give value to the specificities of the context. To assume the notion of public space as central [19]. To go beyond the idea of a mono-functional network dedicated, exclusively, to cycling.

Soil, public space and cycle network must become the elements of an integrated environmental infrastructure [20] that is able to, albeit partially, trigger resilience processes in the urban system [21].

Boston, San Rafael, Melbourne, Zwolle, Enschede and Copenhagen are going in this direction.

4.1 Greater Boston

Developing resilience. Living with water strategies for Greater Boston [22] is a systematic set of measures on a supra-municipal scale. The overall aim of which is to improve the sustainability and resilience of the urban system.

From a programmatic point of view, a series of projects are planned in the residential sector to improve the environmental performance of buildings; in the infrastructural sector in order to reduce the vulnerability of the electricity, natural gas, drinking water and sewage networks; in the transport sector in order to make public and private mobility more sustainable. And this is precisely the sector into which the redevelopment of Western Avenue falls (Fig. 4). A road that plays a major role in linking Central Square and the Charles River in Cambridge.

The project has two main objectives: to moderate car traffic flows and to improve rainwater treatment. The first of these objectives was pursued by reducing the carriageway and expanding the cycle/pedestrian section. The second resulted in the construction of a cycling path out of permeable material while the part immediately adjacent to it consists of green stormwater infrastructures. Both these solutions allow the water to flow towards a pipeline completely separate from wastewaters.

From the hydraulic point of view, this pipeline dedicated to filtered water, both from the permeable floor and from the vegetation, has a double positive effect: it increases rainwater drainage capacity and reduces the pressure on the sewage system. This is why it is possible to say that Western Avenue is both a sustainable and resilient project because the soil becomes not only a support for cycling but also an environmental infrastructure which fits perfectly into the urban context. m the hydraulic point of view, this pipeline dedicated to filtered water, both from the permeable floor and from the vegetation, has a double positive effect: it increases rainwater drainage capacity and reduces the pressure on the sewage system. This is why it is possible to say that Western Avenue is both a sustainable and resilient project because the soil becomes not only a support for cycling but also an environmental infrastructure which fits perfectly into the urban context.

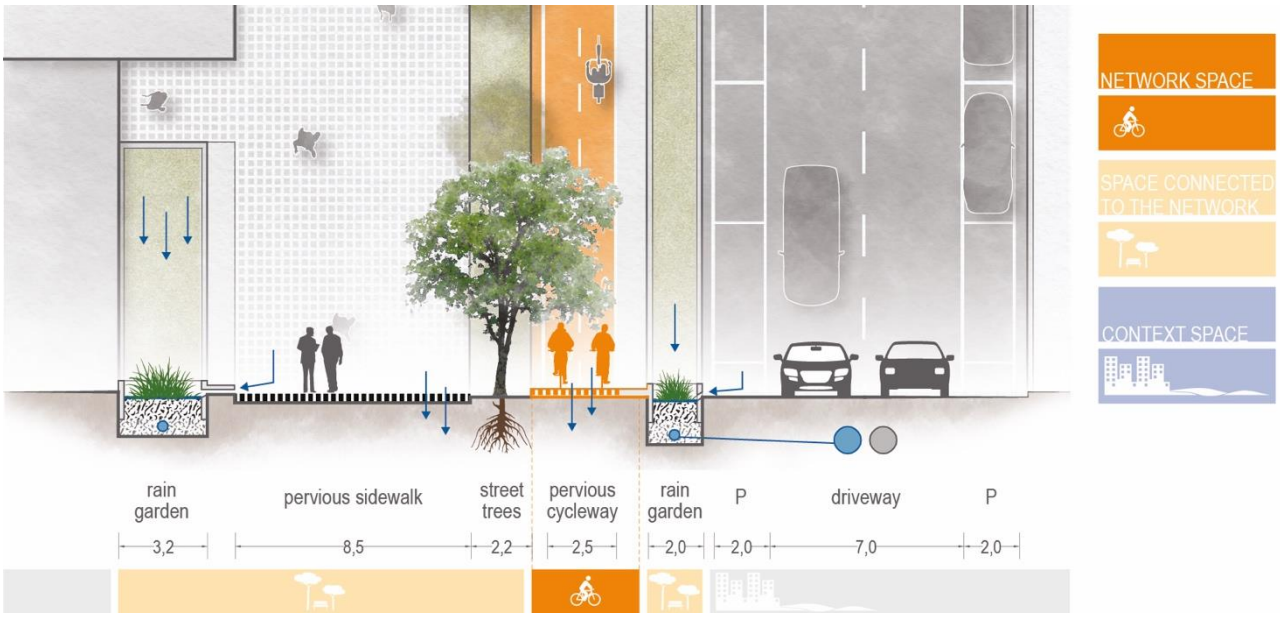

Figure 4: Greater Boston (Cambridge), section and planimetry of Western Avenue. *Original drawing by arch. Angelica Nanni.*

4.2 San Rafael

San Rafael is the most flood-prone city in the entire San Francisco Bay Area. An issue that requires radical change: continuing to raise levees to counter the disastrous effects resulting from urban flooding is no longer enough; it is necessary to anticipate the current trends, planning the most appropriate actions. Said otherwise, the time has come to abandon the logic of emergency. It is on this basis that the *Elevate San Rafael* project was born. Indeed, it is characterized by a multidisciplinary approach to the theme of urban flooding. The strategy is based on an immediate response which includes a series of measures called pilot and catalyst projects with the aim of protecting San Rafael now, to better prepare for the future, and a longer-term response consisting in the re-elaboration of the entire urban structure, its mobility, its infrastructure and its residential and productive areas. As part of the *Pilot and catalyst projects*, a new elevated cycling path is planned along Canal Street and Francisco Boulevard (Fig. 5), which, on the one hand, would complete the Bay Trail route and, on the other hand, would protect the city closest to the sea from flooding. This is a special case for a cycling path: it is not only a bike path but also a project that, through soil modelling, relates to the needs of the urban context because it links the coast with the downtown areas and becomes a tool for sustainable local development.

The prerogatives of this bike path do not however stop there. The track is, indeed, a new environmental infrastructure for the drainage of water that works in two directions: it provides for the replacement of existing metal pipes, now corroded, with new materials and increases the dispersion of water in the landfill used for the elevation. A real stormwater infrastructure that contributes to the greater resilience of the urban system [23].

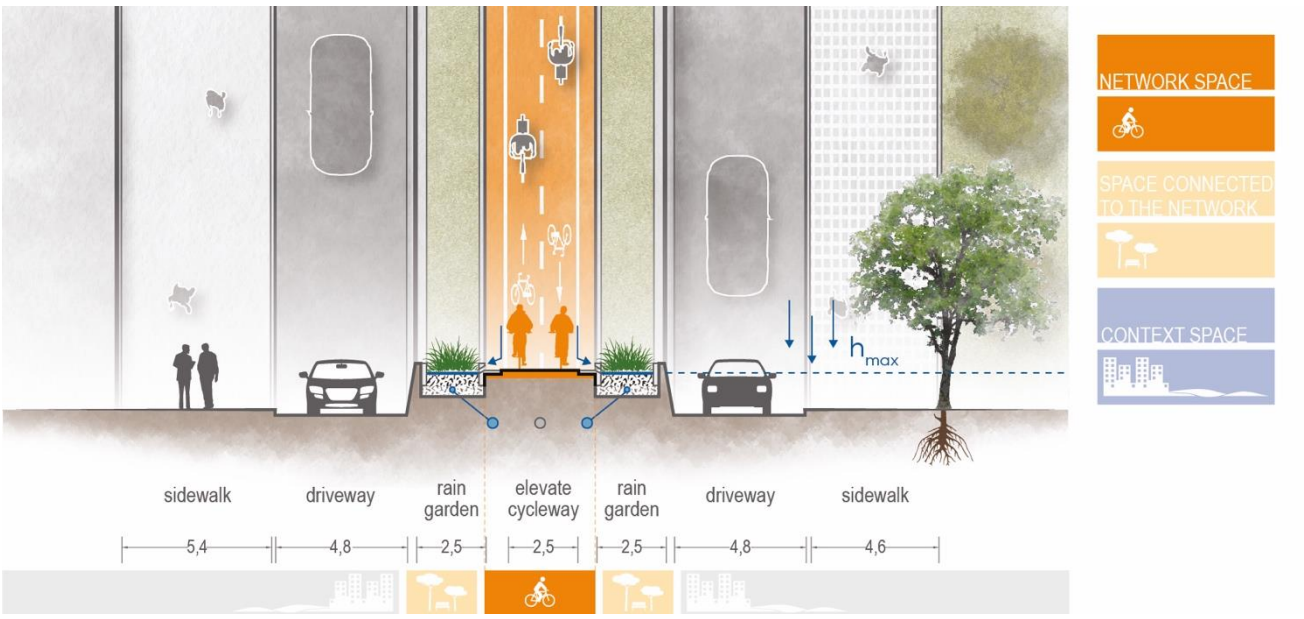

Figure 5: San Rafael, section and planimetry of Canal Street. *Original drawing by arch. Angelica Nanni*.

4.3 Melbourne

The La Trobe Street green bicycle lane is a new cycling lane with its own dedicated space. The design involves the narrowing of the roadbed and the modification of parking stalls. The lane is separated from the street by a traffic divider that also serves as a planting bed for trees. This bed is used to channel stormwater from the street and water that penetrates through the porous asphalt finish of the bike lane. The structure of the planting bed is designed to favour the passive irrigation of the tree roots. On the one hand this limits the risk of flooding and, on the other hand, helps reduce stormwater pollution.

Thermal imagery has shown La Trobe Street to be one of the hottest areas in the city. The planting of trees that cover the bicycle lane serves not only to collect and manage stormwater, but also to create shade and cool the air. However, the trees can also have a negative impact on safety for cyclists. A study identified three actions for reducing this risk: the use of bike-friendly drain covers, pruning of the trees up to a height of 2.4 meters above street level to maintain the efficiency of sunlight and the selection of trees with slender trunks.

The La Trobe Street green bicycle lane belongs to a vaster understanding of the contribution to the implementation of the *Total Watermark: City as a Catchment Strategy* [24] for the integrated water cycle management; the *Urban Forest Strategy* [25] program to create a more resilient, healthier and diversified city by increasing urban plantings; the *Bicycle Plan* [26] whose primary aim is to increase the safety and attractiveness of cycling lanes and the Climate Change Adaptation Strategy, which includes a line of specific actions designed to contrast urban flooding caused by extreme climatic events (Fig. 6).

In light of these brief considerations, The La Trobe Street green bicycle lane is more than a bicycle lane. It is also an environmental infrastructure that integrates soil permeability with stormwater catchment, passive irrigation and the objective of contrasting heat islands [27].

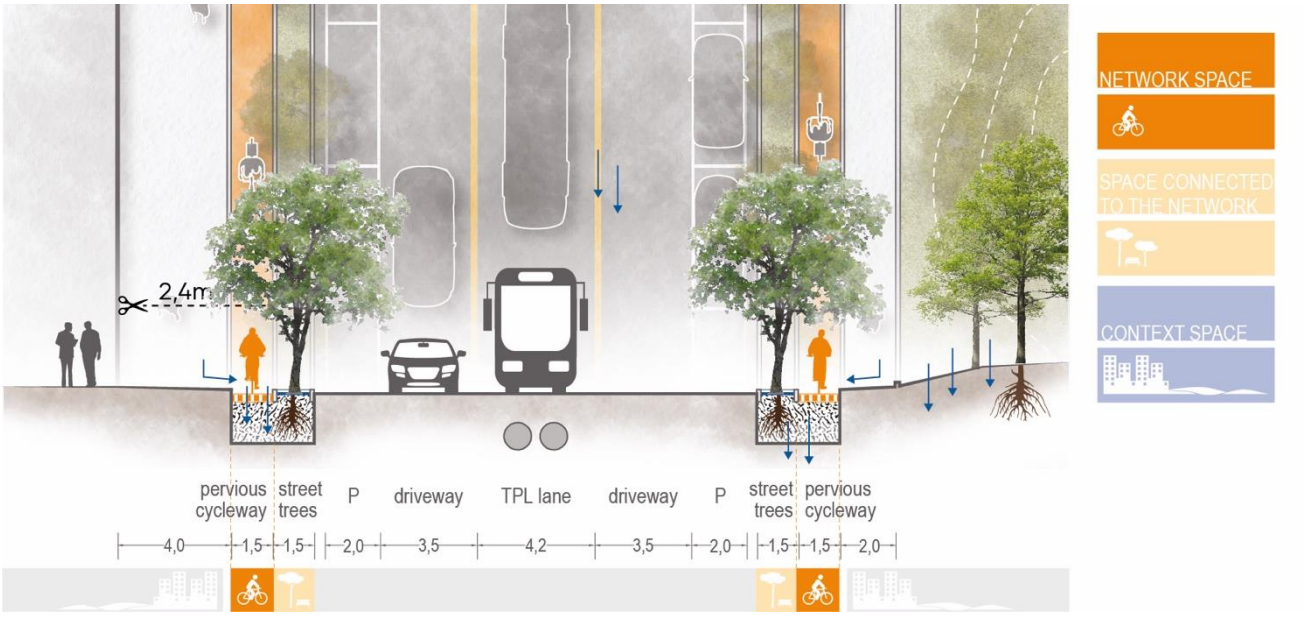

Figure 6: Melbourne, section and planimetry of La Trobe Street green bicycle lane. *Original drawing by arch.* Angelica *Nanni.*

4.4 Zwolle

The Plastic Road is a prefabricated road structure with which a section of the cycle network in Zwolle in the Netherlands was built. Beyond its modest planimetric extension, what is important to emphasize is its degree of innovation. Three fundamental characteristics.

The first concerns a fact of extraordinary interest from the point of view of sustainability: be made with entirely recycled plastic materials and, above all, recyclable even after its disposal.

Another important aspect is the prefabricated production and the design realized in light modules that makes the installation very fast, to the point that the times for its realization are reduced by about 70%. All this is combined with much higher resistance and durability than traditional cycle paths.

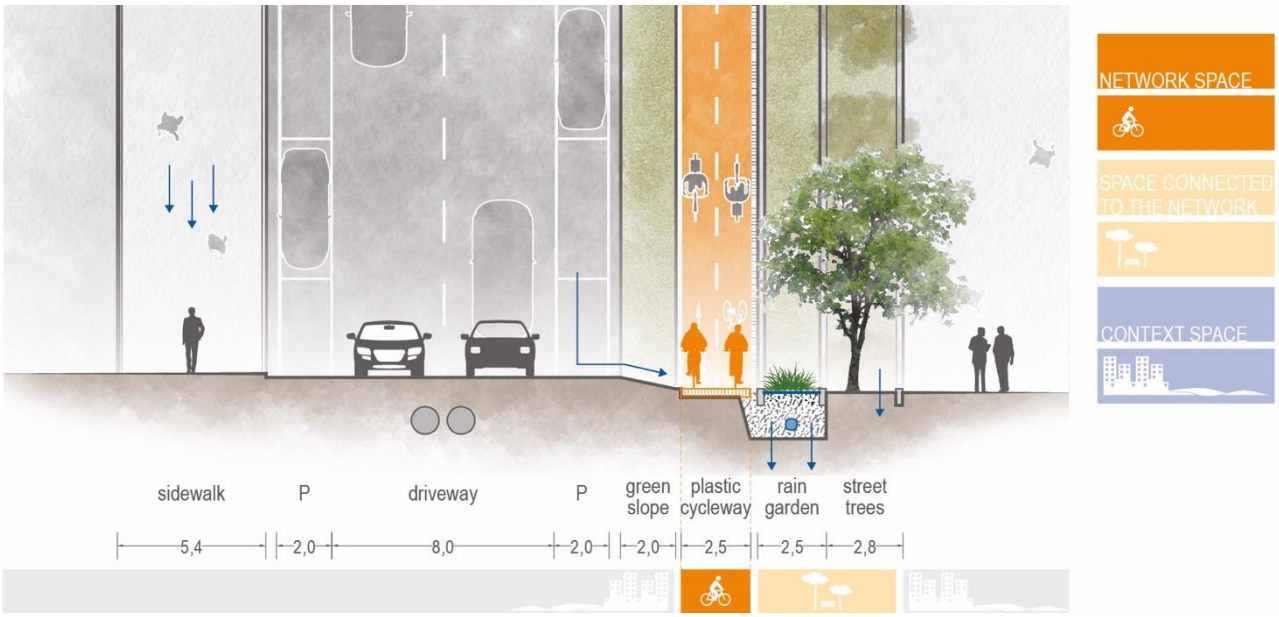

Figure 7: Zwolle, section and planimetry of Plastic Road in Deventerstraatweg. *Original drawing by arch. Angelica Nanni*.

Although these two peculiarities are very relevant from an environmental, social and economic point of view, what matters most with respect to the issue of treatment and management of rainwater is the hollow modular structure inside.This third characteristic was imagined to counteract rain flooding even in the presence of extreme atmospheric phenomena, thus avoiding overloading the sewage system. Considering that the surface of the Plastic Road is completely waterproof, the water collection system consists of a storm drain located at a lower level than the road (Fig. 7).

This storm drain runs parallel to the hedge which helps to manage the flow of water due to the slope, since the ground level is at a lower level than the cycle path.

This allows you to manage rainwater allowing storage, infiltration and evapotranspiration. An effect that is amplified by the system of trees adjacent to the hedge [28].

4.5 Enschede

Enschede is a city in the Twente Region of the Netherlands. The *Water and Climate Adaptation Plan 2022-2026* is an interdisciplinary work with the goal of making Enschede more climate resilient. With this Plan, the Municipality of Enschede, aims to monitor the impacts that climate change could have on vulnerable populations and places. Furthermore, the Municipality designed the project maps and charts that are used to communicate the results of the studies conducted.

One of the first goals of the Plan is an alternative stormwater management to the sewer system, especially when there are extreme weather events. It is an objective that is closely connected to the fact that «a safe and healthy environment requires high-quality groundwater, surface water, and drinking water. The sewer system must function properly in order to minimize residents' contact with wastewater. Furthermore, groundwater levels must not be excessively high or low» [29].

Among the main strategic choices, there are two particularly important ones: Climate-proof designs and Connection to the natural system. And it is precisely for these two strategic choices that the Municipality of Enschede has redesigned the road system of Oldenzaalsestraat. The previous situation consisted of: building, sidewalk, cycle path, a strip of greenery and a single carriageway road with two-way traffic. All this was on the same level.

Today it is different. Both in the sequence (building, sidewalk, greenery, cycle path, driveway) and in the levels: the greenery, located on one side of the cycle path (on the other side is the driveway) is at a lower level in such a way as to receive rainwater. It is a green channel (like a bioswale) designed to concentrate and convey stormwater runoff and recharging groundwater. Its length is about 7 kilometers and it is interrupted only in the presence of cross roads (Fig. 8).

In other words, it is a way to redevelop public space and to counteract the potential negative effects deriving from intense stormwater.

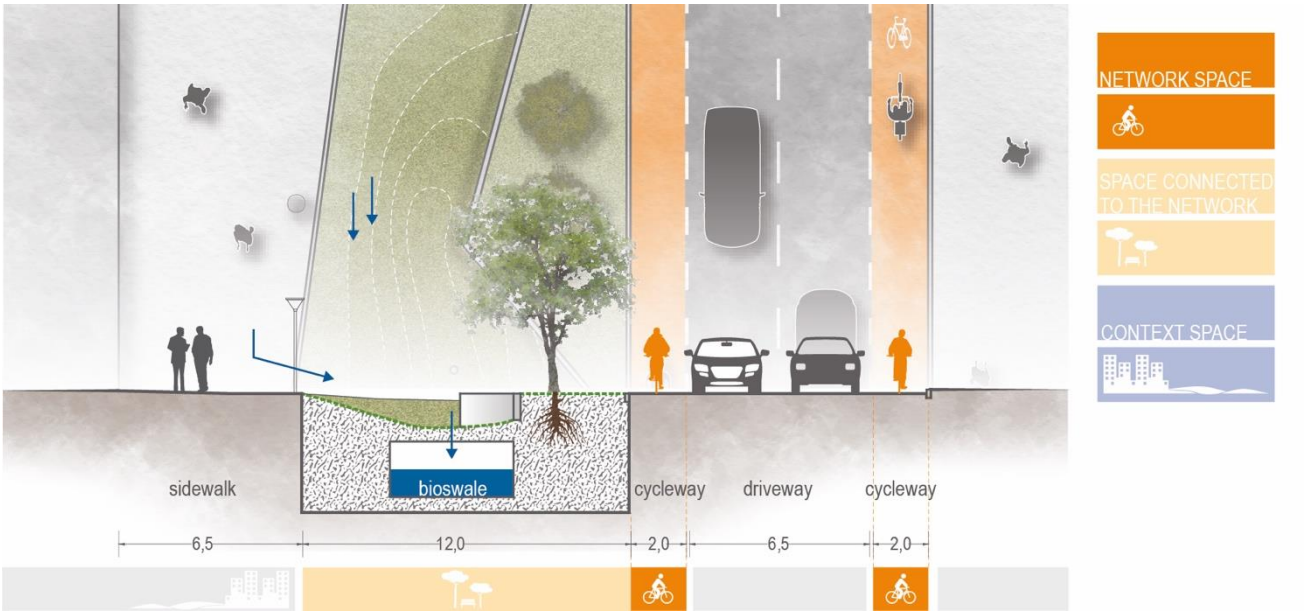

Figure 8: Enschede, section and planimetry of Oldenzaalsestraat. *Original drawing by arch. Angelica Nanni*.

4.5 Copenhagen

«The Little Mermaid is a brilliant fairy tale, but the statue, in my opinion, is a lame monument for a city like Copenhagen. I firmly believe that the greatest monument we have ever erected is our bicycle infrastructure network. It is an intricate and complex work, ever changing and in constant motion and constantly modified and improved by hundreds of thousands of citizens and visitors alike who use it each day. An organic structure of such overwhelming beauty. There is no ownership of this monument. It is completely open-source and it's not reserved for Copenhagen alone» [30]. Despite the city having one of the largest and busiest networks in Europe, two bicycle-only bridges, a high level of safety and security, Copenhagen continues to invest in innovation. The public administration is prioritising the bicycle over any other means of transport, is implementing a series of policies to discourage the use of private cars and, what is more, is creating the conditions for ever faster cycle crossings. But the experimentation in Copenhagen goes further: the cycle network has become a soil project to counteract extreme atmospheric phenomena.

Figure 9: *The Copenhagenize Current* the design project for a prefabricated canal below the cycle path by Mikael Colville Andersen and Steve Montebello. *Original drawing by arch. Angelica Nanni*.

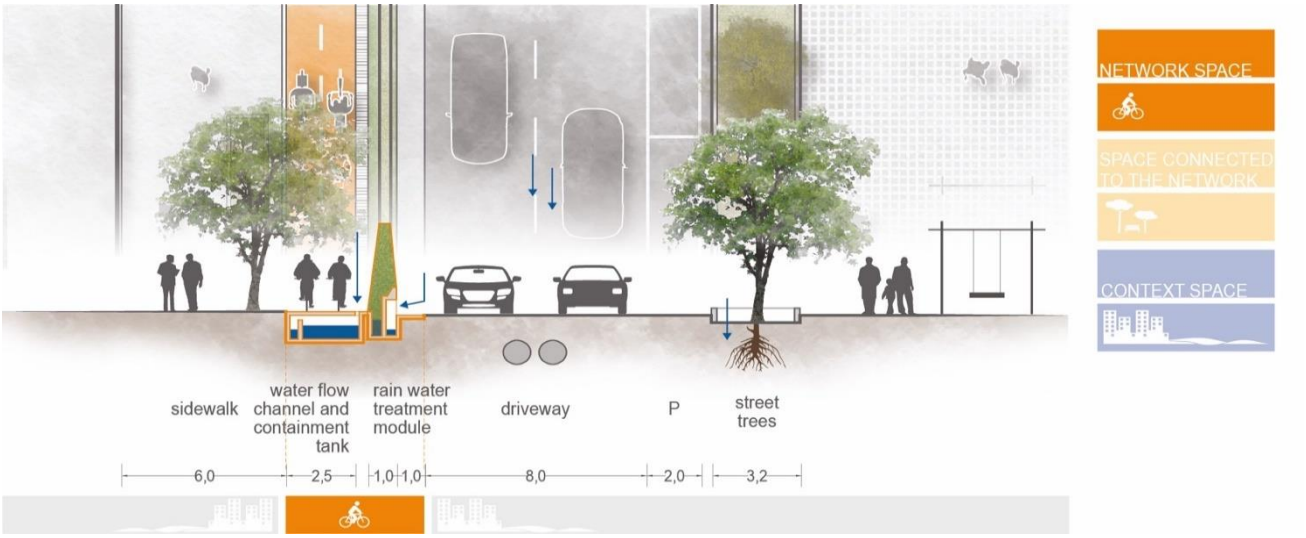

Figure 10: The design concept by Marine Bergen Jensen. *Original drawing by arch. Angelica Nanni*.

One of the best-known design concepts is *The Copenhagenize Current* [31] which was created to provide the space beneath the city's vast network of bicycle lanes with a secondary system of stormwater channels and to improve the city's cycling infrastructure. The system consists of prefabricated concrete channels covered by prefabricated concrete slabs that create the surface of the bicycle lanes. The offer the necessary support for the weight of the city's thousands of cyclists, as well as automotive traffic at lane crossings. In addition, the slabs are fitted with LED lights that improve visibility and heating coils that melt ice during the winter. The system also includes drainage channels at the edge of lanes and street curbs that drain runoff from both sides and capture any detritus. The entire system is easy to install and maintain and, among other things, also provides the possibility to reserve space for the eventual passage of underground urban services. *The Copenhagenize Current* (Fig. 9) integrates the existing sewer network to accelerate stormwater drainage by channelling water toward the river, the sea and Sankt Jørgens Lake. And it is not the only experiment in this direction.

The University of Copenhagen has set up the chair of Urban Landscapes Adapted to Climate Change which has been assigned to Marine Bergen Jensen (Fig. 10), who has developed an urban resilience project. This design concept involves the construction of a double prefabricated channel and a green wall. The double channel has the aim of separating the clean water coming from the cycle path, from the dirty water coming from the driveway. The green wall has two objectives: to create an acoustic barrier which separates car traffic from the pedestrian and cycle path and to allow the capillary rise of rainwater [32].

It is once again a perspective of resilience that presides over the requalification of public space such as The Soul of Nørrebro - Climate Adaptation of Hans Tavsens Park & Korsgade (Fig. 11). It is an integrated project of the Stig Lennart Andersson (SLA group) for adaptation to climate changes. Rainwater is collected and used locally (with the help of the cycle path), while excess water from storms is carried from the park to Lake Peblinge, which is purified by the natural biotopes of the city along Korsgade. «Hydrological, biological and social circuits will work together in a strong symbiosis that not only climate proof inner Nørrebro, but also has a positive effect of the entire city of Copenhagen» [33].

Thanks to different architectural solutions, during extreme weather events the urban landscaping of these public spaces drains heavy flows of water and, when they are truly excessive, channels them into underground reservoirs. In this landscape, bicycle paths participate in achieving these objectives thanks to their necessary slopes, which channel water toward these stormwater infrastructures.

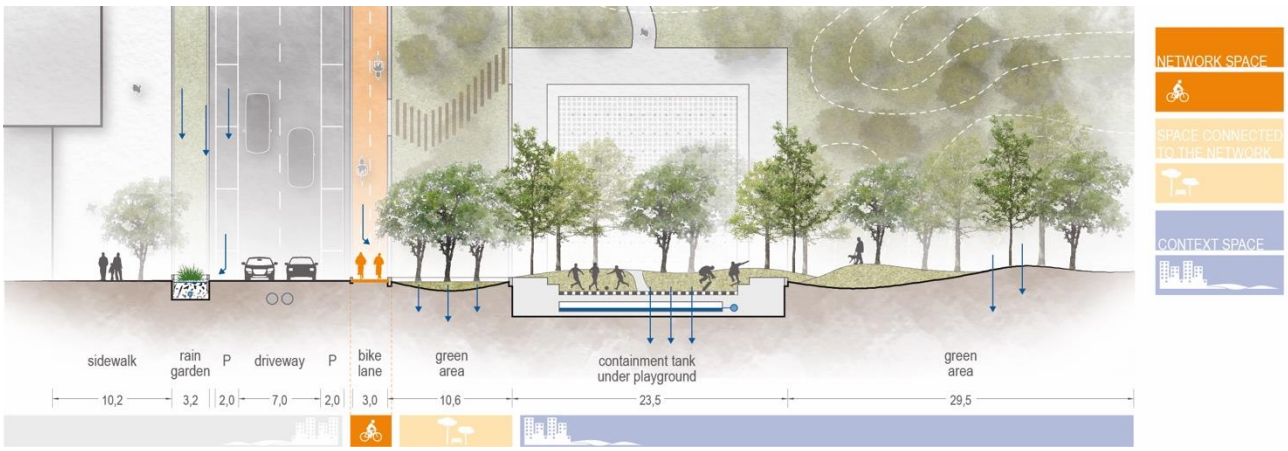

Figure 11: Copenhagen, section of the Hans Tavsen's Park. *Original drawing by arch. Angelica Nanni*.

5. Philadelphia Green Streets Design Manual: a potential cycle path application

Green City, Clean Waters represents an important urban policy that «is making our neighborhoods greener, more vibrant places to live and creating a healthier, more sustainable Philadelphia. Our plan is to reduce pollution and stormwater entering the sewer system under our feet in a way that also enhances the spaces where we live, work, and play» [34]. This urban policy «uses a green-first approach, complemented by grey infrastructure, to reduce combined sewer overflow volumes. Since 2011, hundreds of Green Stormwater Infrastructure projects have been built across the combined sewer area. To measure the progress, Philadelphia Water Department and regulators set a target of delivering 9,564 greened acres by 2036» [35]. The areas on which the *Green City, Clean Waters* focuses are roads, parks, university campuses, areas attached to school buildings, commercial buildings, libraries, museums, courthouses, vacant land and abandoned buildings. The general aim is to avoid overloading the sewer network. This aim is based on several cardinal criteria such as recharging water tables and maintaining and expanding water infrastructures. These are precisely the objectives that the soil project of a cycle network should pursue in order to become an environmental infrastructure. Especially on one side (or both) of the path, in the space that has been defined as associated with the cycle network.

And this is precisely the main interest of the *Green Streets Design Manual* [36] which identifies six green stormwater infrastructures for the collection and management of stormwater in densely urbanized areas.

1. ***Permeable pavement.*** The porous surface and subterranean stone reservoir provide temporary storage, before the water filters into the ground. Naturally, there are many types of porous surfaces, including permeable asphalt and permeable pavers. These latter functions differently than permeable asphalt and concrete. Instead of allowing water to penetrate through the paved surfaces, the pavers typically allow water to pass through the joint spacing between the pavers.
2. ***Stormwater planters or rain gardens.*** Like flower beds, they tend to be longer than they are wider. Flanking sidewalks they are used to manage runoff from the street and sidewalk. The level of the planting media in the planter is lower than the sidewalk and paralleled by a drain at the street edge. Rain gardens are used to manage rainwater by allowing for its storage, infiltration and evapotranspiration (Fig. 12).

Excess runoff is channelled into an overflow pipe connected to the existing sewer network.

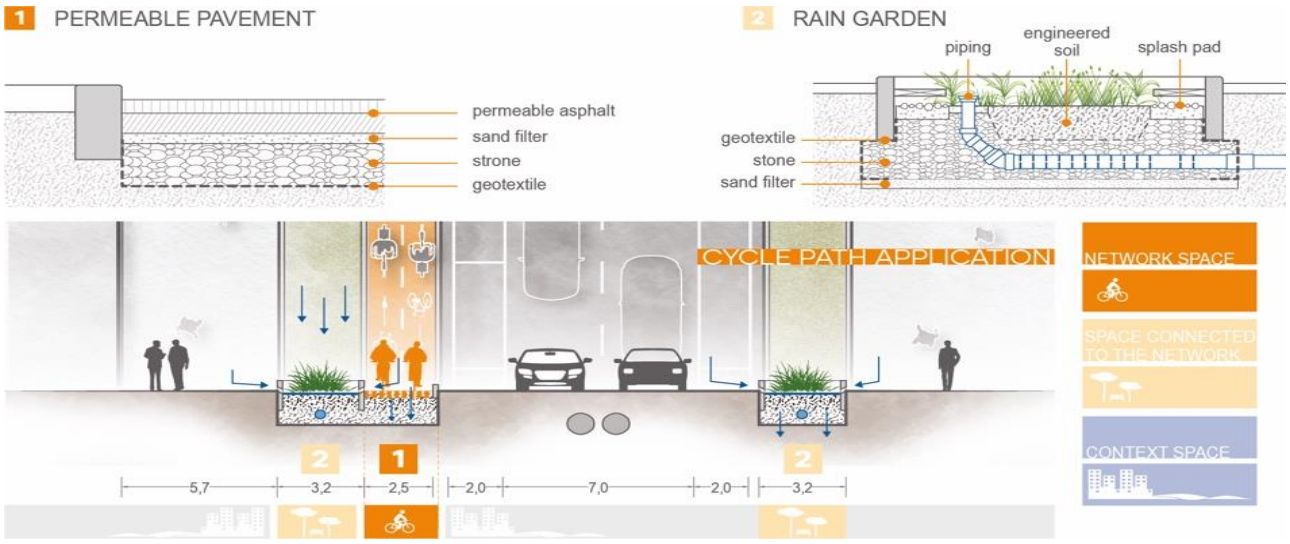

Figure 12: Philadelphia, section and planimetry of Permeable Pavement and Rain Garden: a hypothesis of application to the cycle path. *Original drawing by arch. Angelica Nanni*.

3. ***Stormwater trees.*** This term refers to a tree planted in a bed set into the sidewalk. The upper surface of the planting media is set below street level, and runoff is managed by drains. Water from the sidewalk runs directly into the bed. It is possible to imagine a series of tree beds that are able to manage the highest volume of rainwater, which can successively be filtered or channelled into the sewer system;
4. ***Stormwater tree trenches.*** This is a system of trees connected to an underground infiltration system. On the surface, it resembles a normal sequence of planted trees. However, in reality it is a system composed of trenches dug beneath the sidewalk, finished with a permeable geotextile fabric and filled with stones or gravel, covered by the amount of terrain required to support the trees' root balls. Rainwater flows from the sloping sidewalk and from the street into a horizontal drain connected to the underground infiltration system. Water can be stored in void spaces between stones and used to irrigate the trees and slowly filter through the base layer (Fig. 13).

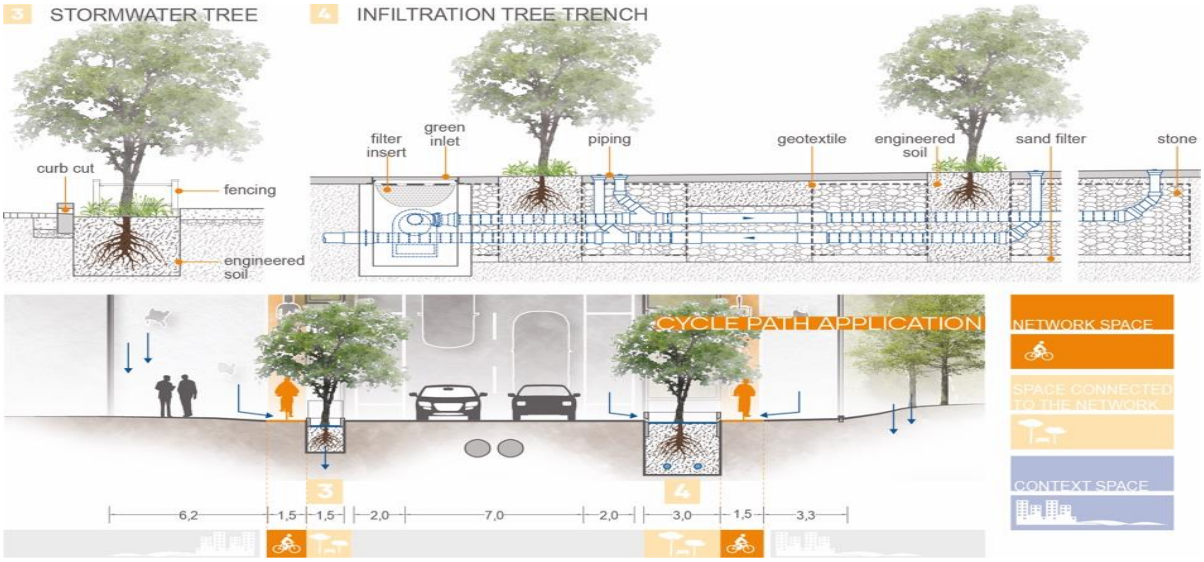

Figure 13: Philadelphia, section and planimetry of Stormwater Tree and Infiltration Tree Trench: a hypothesis of application to the cycle path. *Original drawing by arch. Angelica Nanni*.

5. ***Stormwater bump-outs*** (midblock and corner). These planted extensions of the sidewalk project out into the street, midblock or at intersections to create what is to all intents and purposes a new curb located close to the existing one. A bump-out consists of a layer of stone covered with soil and plants. The slope of the sidewalk deviates the flow of rainwater so that it can be stored, filtered and collected by plants (evapotranspiration). Excess runoff can be channelled into the existing sewer network.
6. ***Green gutter*.** This narrow, elongated and shallow landscaped strip along the street curb (or that of a bicycle lane) that manages stormwater runoff. The upper layer of the planting media is set lower than the street level to aid runoff from the street and sidewalk. The system attenuates stormwater flows, provides for storage and, in some cases, filtration and evapotranspiration. In flow-through green gutters, overflow runoff can be conveyed to the existing storm drain system, either through an underdrain tied to the existing storm drain system, or as shallow concentrated flow that is conveyed downstream to an existing inlet (Fig. 14).

Green Stormwater Infrastructures are extremely important for cycle networks. They represent a plurality of soil-water-plant systems that can be very useful to intercept rainwater and to infiltrate a part into the soil and evaporate the remaining portion into the air. This, without any pressure on the existing sewer system. In other words, the Green Stormwater Infrastructures considers stormwater runoff as a resource to be incorporated into the urban environment instead of a waste product requiring removal and treatment.

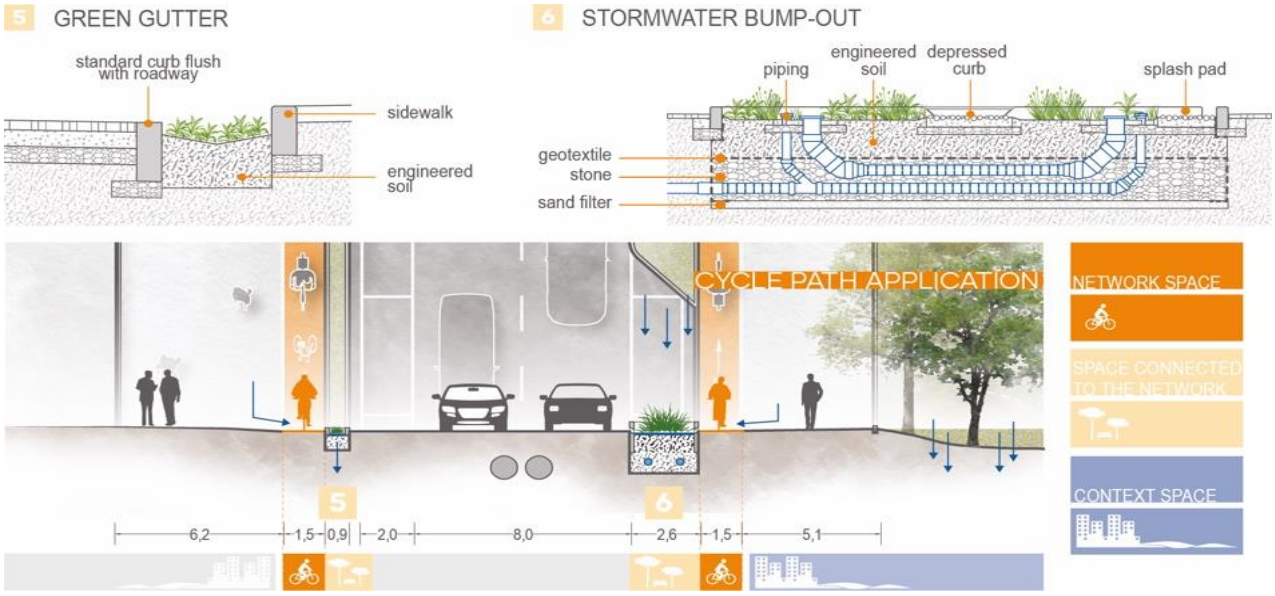

Figure 14: Philadelphia, section and planimetry of Green Gutter and Stormwater Bump-Out: a hypothesis of application to the cycle path. *Original drawing by arch. Angelica Nanni*.

6. Conclusion

This brief review of projects and intervention programs, each of which deserved greater in-depth analysis, has made it clear that there is potentially a relationship between the cycle path, the collection and management of rainwater. Looking closely, the cycle path is not a strip of asphalt but a much larger and more complex system: the comparison of case studies says that the system is mainly made up of three types of spaces, strictly interrelated to each other.

The network space: the area on which cycle traffic passes that can be used for permeable pavement. This porous surface provides temporary storage before the water filters into the soil. The network space could also entail the prefabricated concrete channels which, placed under the path, would allow the collection and management of water. The space connected to the network: all the projects examined have a relationship with vegetation. It is necessary to go further by integrating Green Stormwater Infrastructures that contribute to increasing the permeability of the soil on one or both sides of the cycle path. Finally, the context space within which the cycle network opens itself up to the city; it relates to the places it crosses; it establishes privileged relationships with the public space.

Deciding how to make the network space, associated space and context interact, concerns the geomorphological conditions, the width of the road section, the possibility of integrating the underground system or not and, more generally, the possibility of creating alternative solutions to the sewer network for the collection and management of rainwater.

Unfortunately, the region of Abruzzo is going in another direction. As shown earlier, the Biciplan of Pescara is emblematic example of a sector plan of the Sustainable Urban Mobility Plans. In other words: nothing more than what the law requires. The perspective of intervention must be reversed bringing the relationship between the cycle network, collection and management of rainwater within the ordinary themes of the urban plan. This is what Boston, San Rafael, Melbourne, Zwolle, Enschede and Copenhagen have done. In Pescara and the rest of all the mid-Adriatic region of Abruzzo, it has become necessary to make a multiplicity of strategic choices. Three are the main ones.

Firstly, it is necessary to exit the sector logic: the cycle network is not a small highway. It does not remain at the side of the territory, with which it fails to activate any link. It is in relation with the places it passes through and opening to the interdependence between infrastructure and environment: The Soul of Nørrebro - Climate Adaptation of Hans Tavsens Park & Korsgade is the clearest evidence of this. To achieve this, it is essential to focus on smaller networks and, in particular, slow mobility. For the mid-Adriatic region of Abruzzo, it would be a historic reversal of the trend: the perspective of transport engineering would be overturned. Transport engineering, from the second post-war period, imposed the idea that to solve the problems of mobility and accessibility one should invest only in large infrastructure. Pescara is an undisputed icon of this method. Its construction was strongly influenced by the railway along the coast, by the State Road 16, the A 14 Motorway, the "Asse Attrezzato" and the junctions connecting with the urban road network.

The second: the cycle path cannot be considered, as in Italian legislation, only an itinerary with specific signage, reserved for the circulation of velocipedes whose roof covering is made with a layer of bitumen and subsequent spreading of gravel, even colored. The cycle path must be a soil project. A project in which the soil, shaped in depth or in elevation, meets the dual objective of supporting the transit of bicycles and countering flood events. A soil project that, especially in situations of high residential density, thanks to the permeability of the cycle path, or the installation of prefabricated canals below it, or collection grilles creates, in fact, an alternative to the urban drainage system that, in the presence of extreme atmospheric phenomena, almost never manages to dispose of the enormous amount of water that is poured in a restricted time within the city.

The second choice introduce the third one. And it is, only apparently, the most paradoxical choice. If the cycle network must work even in the absence of traffic when atmospheric events occur, then the network loses its support function for the bicycle transit to acquire a permeable body which has the purpose of reducing the recovery times of the area affected by the negative effects of a flood. To achieve this result, the project can go towards the permeability of the cycle path (Boston, Melbourne, San Rafael), or provide for the installation of underlying prefabricated canals (Copenhagen), grids for rainwater collection (Zwolle) or create an integrated cycle path with green stormwater infrastructures (Enschede). Respecting this third strategic choice means going in towards the direction of full sustainability because it would remedy the paradox of the cycle path as a work of soil waterproofing.

The cycle network as a soil project is not just a vision for the future. It can be so much more. The technical-architectural devices used in the case studies, although not explicitly provided by Italian legislation (national and regional), are not even prohibited. This means that it is necessary to innovate. And this is precisely the responsibility that, ultimately, who plans a cycle network must assume: making it become a part of a wider territorial project capable of triggering not only sustainable development processes but also urban resilience.

* This contribution is the result of a common reflection of the authors. However, the following paragraphs were written by Antonio Alberto Clemente: 1. Introduction, 2. Sector legislative framework, 4. Case studies, *4.1 Greater Boston*, *4.2 San Rafael*, *4.3 Melbourne*, *4.4 Zwolle*, *4.5 Enschede*, *4.5 Copenhagen*, 5. Philadelphia Green Streets Design Manual: a potential cycle path application, 6. Conclusion. Angelica Nanni wrote the paragraph 3. Biciplan

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