NATURE-BASED SOLUTIONS FOR URBAN ADAPTIVITY

Regenerating Former OSI-GHIA Industrial Site

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Nature-Based Solutions For Urban Adaptivity

Regenerating Former OSI-GHIA Industrial Site

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ABSTRACT

In recent years, the globally increasing challenges affecting modern societies have been brought to significant attention. The growing urbanization along with the destructive effects of climate change, such as prolonged heat waves, urban heat island and flash floods may lead to humanitarian and environmental disasters if not managed properly. This implies the need to urgently foresee proper mitigation and adaptation strategies. As such, the "nature-based solutions" are launched based on biophilic approach as a promising tool for sustainable development and urban adaptivity. Being capable of addressing some priority areas such as climate change, disaster risk reduction, human health and well-being, water and food security, they also target aspects such as carbon sequestration, phytoremediation, run-off water management, ecosystem restoration and sustainable use of energy in urban areas providing environmental, social and economic resilience.

Contemporary advances in science and technology provide the possibility to implement "nature-based solutions" in formerly "doubtful" spaces: urban brownfields, built surfaces, under roofs or on rooftops, and even inside buildings. Besides, NBS are flexible to be incorporated into complex hybrid architecture systems, acting simultaneously with other strategic tools such as the adaptive reuse of abandoned or underused spaces.

This research has launched a profound Investigation and analysis of the theory of NBS, defining certain tools and strategies for the implementation of NBS and various criteria to simulate and assess their effectiveness in the built environment. The verification of this hypothesis has been carried out by applying these strategies on the former OSI-Ghia industrial site in Turin. A comparative microclimatic assessment has been conducted by using Envi-met software, along with the economic evaluation for adaptive reuse and urban regeneration project organized in phases, providing a multidisciplinary developing pattern for the actual challenges.

Keywords

Nature-based solutions (NBS), European Green Deal, Biophilic design, climate change, mitigation, adaptation, adaptive reuse, Envi-met

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List of Acronyms

CAS	Climate Adaptation Services
CC	Construction Cost
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici
EBA	Ecosystem-Based Adaptation
EBM	Ecosystem-Based Mitigation
EbMgt	Ecosystem-Based Management
EC	European Commission
Eco-DRR	Ecosystem-Based Disaster Risk Reduction
EE	Ecological Engineering
ER	Ecological Restoration
ETCCDI	Expert Team on Climate Change Detection &Indices
FLR	Forest Landscape Restoration
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GI	Green Infrastructure
IRR	Internal Rate of Return
IUCN	International Union for Conservation of Nature
LT- LEDS	Low Emission Development Strategies
NI	Natural Infrastructure
NBS	Nature-Based Solutions
NDCs	National Climate Plans
NPV	Net present value
PM	Particulate Matter
PMV	Predicted Mean Vote
SDGs	Sustainable Development Goals SDGs
SuDS	Sustainable Drainage Systems
UCCRN	Urban Climate Change Research Network
UFP	Ultrafine Particles
UHI	Urban Heat Island
UN	United Nations
UNFCCC	UN Framework Convention on Climate Change
VAT	value-added tax
VOCs	Volatile Organic Compounds
WHO	World Health Organization

Introduction

Living with nature has a long history in the evolution process of civilization. Starting from ancient times nature has been generously integrated in the urban context, initially with more focus on aristocratic or wealthy stratum of society, with furter development in public spaces and even integration of natural forms in various design styles. The 20th century opened a completly new dimention for the nature in the built environment. The Avant-garde approach to introduce the distructive side of the built stock on the environment in the mid century was then followed by the investigation of nature, seeking solutions for the new concerns of the late 20th century: climate change, ozone depletion, loss of biodiversity, and call for sustainable development (Leach et al., 2010). The initial outcomes of these investigations were Brundtland Report (UN, 1987) elaborated through the Agenda 21 (UN, 1992) and the 17 Sustainable Development Goals (SDGs) (UN, 2015). For the sustainable development and transformations of the cities in the frameworks of the above mentined researches, the European Commission (2015) launched "nature-based solutions", a series of actions that are "inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions" European Commission (2019).The effectiveness of this approach incorporated into a complex system of green technologies can be analysed through the assessment of thermal performance, air quality, acoustic insulation and noise reduction, urban run off water management, and biodiversity.

This research focuses on the interpretation of "nature-based solutions" as a tool for urban resilience strategies, discussing its versatile benefits and effects in the built environment. Further experiments have been applied on the former OSI Ghia factory, an abandoned industrial area in Turin, illustrating the results of environmental assessment tools along with economical evaluation for an adaptive reuse and urban development project in the area.

Research Questions

1 What does the term "Nature-based solutions" refer to? Definitions, origins, frameworks, and typologies.

2 In which ways the nature-based solutions are capable of acting for urban adaptivity?

3 Which are the novel tools and strategies that can be helpful to address climate change impacts?

4 How effective is the implementation of nature-based solutions in the urban environment?

CHAPTER 1
METHODOLOGY

Methodology

This research is conducted based on a methodology that considers NBS not only as a tool for the Biophilic design approach but also as a mitigation and adaptation strategy for urban adaptivity to climate change challenges. The methodology incorporates several theoretical, analytical and experimental components, including investigation and analysis of the theory, defining tools and strategies, an overview of case studies, implementation of the defined tools and evaluation of obtained results. Having adopted a circular logic it aims to represent the clear pattern of a complex system in which the components appear in a repetitive sequence with a regenerative approach to enhance environmental, economic and social resilience in urban areas.

Investigation and analysis of the theory

The study of the theory of biophilic design and nature-based solutions (NBS) is the very initial step of the development of the thesis, considering that the entire further process is structured based on the analysis of the theory and its possibilities. The first two chapters focus on the definition and conceptual interpretation of the terms, concept, origins, principles and typologies of NBS, emphasizing their potential as Ecosystem-related approaches and responses to societal challenges related to climate change. The capabilities of mitigation and adaptation to climate change challenges along with other various aspects such as enhancing biodiversity, social and economic benefits and their constructive role in developing resilience in urban areas are later discussed with a focus on the built environment.

Defining tools and strategies

Following a wide range of research in various fields of design approaches, strategies, tools and software, and comparing with the actual challenges related to the topic, this research has adopted a certain selection of tools and strategies applicable for further analysis in the next phases. These are selected based on different aspects of profitability, including environmental, economic and social, specific features of the study site, as well as analytical abilities to create comparative quantitative results before and after implementation. In this section, NBS

are defined as tools to deal with both general climate change-related challenges and local site-related constraints including urban integration, acoustic isolation, remediation, etc. While for numerical analysis some software and techniques, their advantages and limitations have been discussed, aiming to introduce a series of available tools to be used selectively during the research phases.
Detailed discussion related to this section is represented in the fourth chapter of this research.

Case studies

The case studies represented in chapter five of this research are selected among the existing samples with similar approaches and characteristics to this research and the site, such as the environmental and site-specific challenges, runoff water mismanagement, urban heat island effect, contamination, urban disintegration, abandonment, etc. This section aims to conduct a parallel comparison with the global experience of the actual use and lasting effects of NBS in an urban environment.

Implementation of the defined tools

The verification of the hypothesis is realized through the application of selected tools on the former OSI-GHIA industrial site in Turin. Implementation of the defined tools has been carried out along with their integration with other tools and policies. In this respect design strategies and analytical procedures have been accompanied by further calculations and simulation software in order to assess the feasibility of the design within the resilience framework. Consequently, a wide range of nature-based design strategies, such as wetlands, green roofs, green walls, permeable surfaces, urban plants, water bodies, etc. have been selected and applied in the design process. The modeling and simulation of the applied strategies have been developed using the Envi-met software aiming to conduct a microclimatic analysis.
The various types of input data were collected from the geoportal of the city of Turin, Arpa Piemonte as well as google maps so as to map and analyze the site, urban components and surfaces.

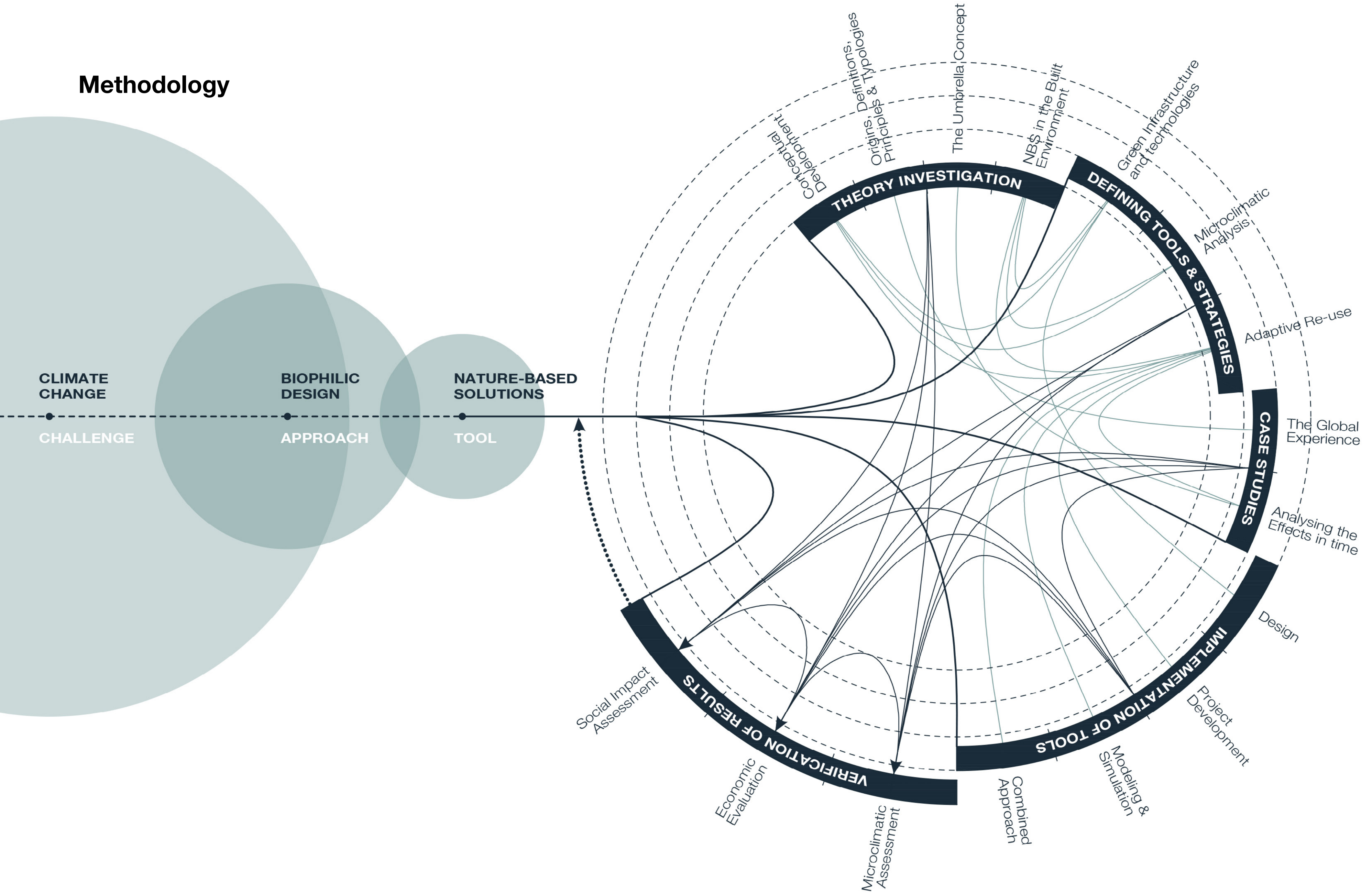
Evaluation of results

In this step, the research puts the data obtained before the interventions in comparison with the one generated as a result of interventions. In this manner, it illustrates the effectiveness and feasibility of the developed strategies to be verified as an acceptable one or to re-enter the cycle of the development process in order to follow alternative patterns.

Within the Envi-met software, the simulation has been performed once for the actual site situation and another time after the implementation of proposed nature-based solutions, adaptation and mitigation strategies. Consequently, it became feasible to assess the microclimatic conditions, The NBS and other proposed strategies in a quantitative sense of manner. The assessment has been developed taking into account the potential air temperature, surface temperature, wind velocity and The (PMV) thermal comfort index.

The comparative approach, along with a parallel simplified economic evaluation is meant to justify the effectiveness and feasibility of the selected strategies in consecutive phases.

Methodology



CHAPTER 2
NATURE BASED SOLUTIONS

2. The advent of nature-based solutions and their conceptual development to respond to societal challenges.

The second millennium started with an exceptional attention to the integration of nature in lifestyle. The early century widespread investigations introduced Nature Based Solutions (NBS) as a strategy for sustainable development, considering the appropriate use of natural features and processes, with the aim of tackling socio-environmental challenges such as the climate change, water security, water pollution, food security, human health, biodiversity loss, and disaster risk management.

The understanding of nature in architectural design is often conceptualized by biophilic design. The theory of biophilia was first introduced by Erich Fromm (1964) and later defined as "the innate tendency to focus on life and lifelike processes" by Edward Wilson (1984). Biophilic design was adapted in the architectural field only in the 21st century, aiming to contribute to sustainability, ensuring the connection with nature, along with effective building performance and management of the resources. There are various conceptual frameworks for biophilic design in architecture, nonetheless, the most often used are Browning and Ryan, 2020; Kellert, 2008b, 2018. These are even the conceptual basis of some certificates such as LBC, WELL, and LEED.

Comparing these three interpretations, Kellerts (2008b, 2018) ideologies are based on the biophilia theory and evolutionary psychology, while Browning and Ryan(2020) interpret human-nature relationships: physiological health and well-being, functionality and performance. The table represents the dimensions, elements and attributes (Kellert, 2008b), the experience and attributes (Kellert, 2018), as well as the categories and patterns of biophilic design (Browning and Ryan, 2020) (Figure 1). Furthermore, the benefits of biophilic design in addressing the challenges of sustainability is represented in figure 2 (Zhong, Schroder, Bekkering, 2021).

In this context NBS appears to become a tool to implement the key frameworks of biophilic design along with other innovative strategies with the perspective of reaching the environmental goals.

This chapter investigates the concept and origins of the NBS, focusing on various definitions, the framework and typologies, as well as the approaches to respond to societal challenges.

2 Dimensions, 6 Elements and 7 Attributes of Biophilic Design (Kellert, 2008b)					
I. Organic or Naturalistic				**I. Place-based or Vernacular**	
1. Environmental features	**2. Natural shapes and forms**	**3. Natural patterns and processes**	**4. Light and space**	**5. Place-based relationships**	**6. Evolved human nature relationships**
• Color • Water • Air • Sunlight • Plants • Animals • Natural materials • Views and vistas • Facade greening • Geology and landscape • Habitats and ecosystems •Fire	• Botanical motifs • Tree and columnar supports • Animal (mainly vertebrate) motifs • Shells and spirals • Egg, oval, and tubular forms • Arches, vaults, domes • Shapes resisting straight lines and right angles • Simulation of natural features • Biomorphy • Geomorphology • Biomimicry	• Sensory variability • Information richness • Age, change, and the patina of time • Growth & efflorescence • Central focal point • Patterned wholes • Bounded spaces • Transitional spaces • Linked series & chains • Integration of parts to wholes • Complementary contrasts • Dynamic balance and tension • Fractals • Hierarchically organized ratios and scales	• Natural light • Filtered and diffused light • Light and shadow • Reflected light • Light pools • Warm light • Light as shape and form • Spaciousness • Spatial variability • Space as shape and form • Spatial harmony • Inside-outside spaces	• Geographic connection to place • Historic connection to place • Ecological connection to place • Cultural connection to place • Indigenous materials • Landscape orientation • Landscape features that define building form • Landscape ecology • Integration of culture and ecology • Spirit of place • Avoiding placelessness	• Prospect and refuge • Order and complexity • Curiosity and enticement • Change and metamorphosis • Security and protection • Mastery and control • Affection and attachment • Attraction and beauty • Exploration and discovery • Information and cognition • Fear and awe • Reverence and spirituality

3 Experiences and 25 Attributes of Biophilic Design (Kellert, 2018)		
1. Direct Experience of Nature3	**2. Indirect Experience of Nature**	**. Experience of Space and Place**
• Light • Air • Water • Plants • Animals • Landscape • Weather • Views •Fire	• Images • Materials • Shapes and forms • Texture • Biomimicry • Information richness • Bounded spaces • Color • Natural geometries • Change, age and the patina of time • Simulated natural light air	• Prospect and refuge • Organized complexity • Mobility • Place • Transitional spaces • Integrating parts to create wholes

3 Categories and 15 Patterns of Biophilic Design (Browning and Ryan, 2020)		
1. Nature in Space	**2. Natural Analogues**	**3. Nature of the Space**
• Visual connection with nature • Non-visual connection with nature • Non-rhythmic sensory stimuli • Thermal & airflow variability • Presence of water • Dynamic & Diffuse Light • Connection with natural systems	• Biomorphic forms & patterns • Materials connection with nature • Complexity & order	• Prospect • Refuge • Mystery • Risk/Peril • Awe

FIGURE 1:
The dimensions, elements and attributes (Kellert, 2008b), the experience and attributes (Kellert, 2018), and the categories and patterns of biophilic design (Browning and Ryan, 2020).
Source: Zhong, Schroder, Bekkering, 2021

Benefits of Biophilic Design in Addressing the Challenges of Sustainable Architecture

Level of Efficancy	The 17 SDGs	Challenges in Sustainable Architecture	Benefits of Biophilic Design	Most Relevant Biophilic Design Elements
●○○	1. No Poverty	- Affordability of housing	- Reduce energy and construction material costs	Air , Daylight , Plants Materials, texture and color
●○○	2. Zero Hunger	- Food supply	- Enable food production	Plants
●●●	3. Good Health and Well-Being	- Healthy and comfortable indoor environment - Non-toxic substances and environment - Obstruct disease transmission and bacterial contact - Physical exercise spaces	- Reduce air pollution, optimise air quality and thermal comfort, - Enhance positive emotions and physical activity, - Increase healing rates, - Reduce stress, - Provide psychological restoration	Air, Daylight, Plants, Landscape Images, Materials, texture, and colour Prospect and refuge Enticement (peril and mystery)
●●○	4. Quality Education	- Performance in learning environments - Training and education of sustainable performance knowledge	- Increase cognitive performance (attention capacity, creative performance, and memory restoration) - Raise environmental awareness	Air, Daylight, Plants, Landscape
●○○	5. Gender Equality	- Inclusiveness of diverse genders	- Provide examples of considering gender in design	Plants Landscape
●○○	6. Clean Water and Sanitation	- Rainwater collection and purification - Resilience in the face of water-related climate change	- Improve water management (stormwater management, water recycling, and water runoff quality)	Water Weather
●●○	7. Affordable and Clean Energy	- Energy consumption of heating or cooling, lighting - Geographical, climatic, and cultural conditions	- Decrease energy consumption (enhance building passive cooling and lessen the perceived temperature)	Air Daylight Plants Weather Mechanisms
●●○	8. Decent Work and Economic Growth	- Health and productivity of employees in workplaces	- Increase worker productivity - Increase retail potential	Air Daylight Plants Landscape

FIGURE 2:
Benefits of Biophilic Design in Addressing the Challenges of Sustainable Architecture (Zhong, Schroder, Bekkering, 2021).

Level of Efficancy	The 17 SDGs	Challenges in Sustainable Architecture	Benefits of Biophilic Design	Most Relevant Biophilic Design Elements
●●○	9. Industry,Innovation and Infrastructure	- Physical and digital infrastructure develop-ment - Stricter building standards in terms of pollution, energy consumption, safety, and health	- Enrich building appearance - Provide examples of the use of virtual reality in design - Promote policy or financial incentives - Increase building rating	Plants, Forms and shapes Time and seasonal changes Patterns and geometries Mechanisms Complexity and order
●○○	10. Reduced Inequalities	- Accessibility of public infrastructure - Inclusiveness for all groups and social responsibility from all members of society	- Provide accessible and public green/blue spaces	Water Plants Landscape
●●	11. Sustainable Cities and Communities	- Safety, inclusiveness, robustness, and resilience of cities and settlements - Affordability, accessibility, mobility, and health of houses and infrastructure	- Increase liveability and enable higher density - Decrease violence and crime	Water, Air, Daylight, Plants Landscape, Weather Connection to place
●●○	12. Responsible Consumption and Production	- Durability and life cycles of the building - Proper use of local materials	-Increase lifespan - Strengthen the use of indigenous materials and native plant varieties	Plants, Materials, texture, and color
●●●	13. Climate Action	- Climatic comfort with minimum energy consumption - Resilient to changing conditions - Sensitivity to local culture, topographic, and climatic conditions - Climate adaptation solutions with co-benefits	- Reduce energy consumption through vegetative climatic effects - Reduce the urban heat island effect - Attenuate noise - Enhance wind protection -Sensitive to local topography and climate	Water Air Daylight Plants Landscape Weather Connection to place
●○○	14. Life below Water	- Low-cost water management - Regeneration of polluted land close to sea	- Reduce water pollution	Water, Plants, Animals
●●○	15. Life on Land	- Protection, restoration, and support of ecosystems and biodiversity	- Improve biodiversity, - Provide habitats for animals in urban areas	Plants, Animals Connection to place
●○○	16. Peace, Justice & Strong Institutions	- Safety, inclusiveness, and affordability of public spaces and institutions	- Offer public shelter and shade spaces	Plants Prospect and refuge
●●○	17. Partnerships for the Goals	- Collaboration among different stakeholders - Associations and networks of professionals	- Present examples of collaboration - Allow professional institutions and organisations to work together	All biophilic design elements

NATURE INCORPORATION

Bring in or artificially create natural elements, phenomena, and processes, and emphasize them through multi-sensory experience

NATURE INSPIRATION

Imitate nature (often knows as biomimicry) and evoke the sense of nature though the delicate placement of natural features.

NATURE INTERACTION

Arrange spaces based on evolved human-nature relationships to experience nature-like environments and establish connections with the natural system or between various spaces.

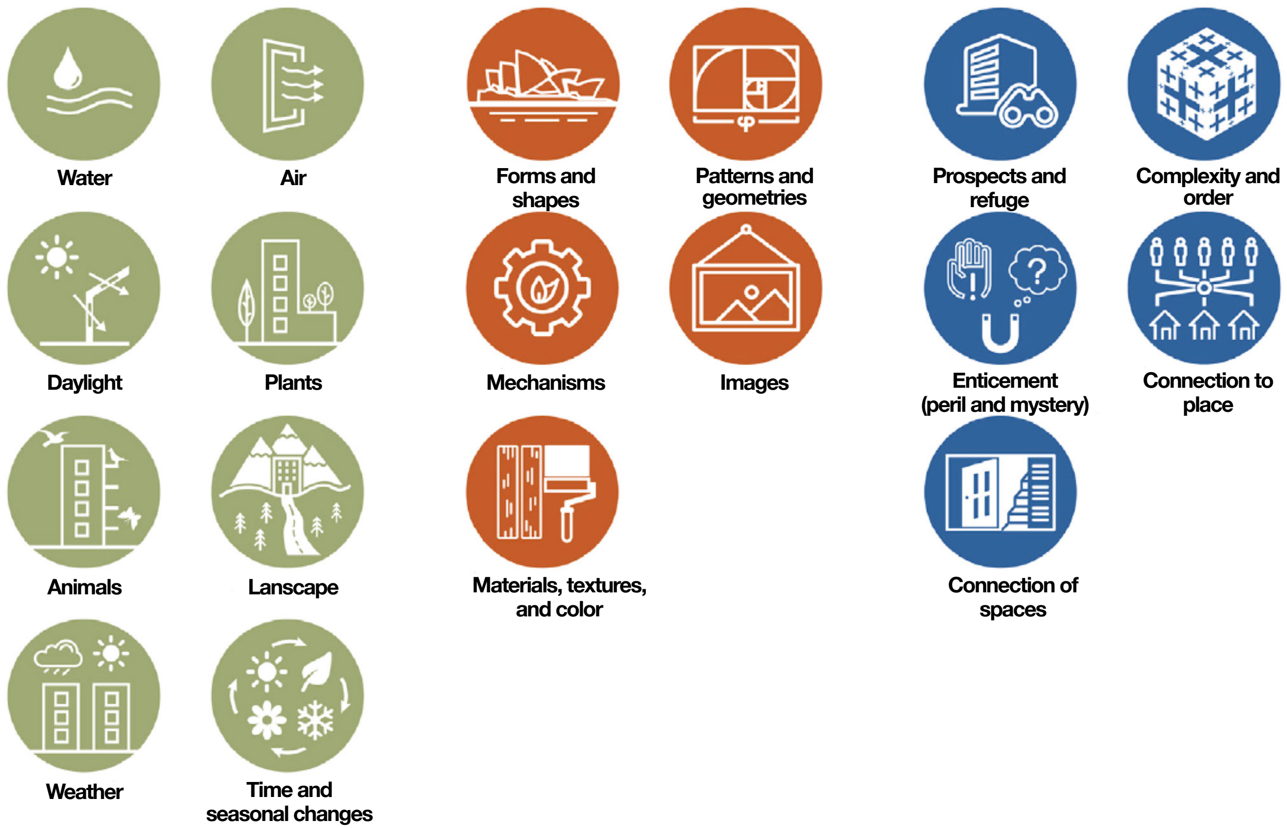


FIGURE 3:
Biophilic Design frameworks: three design approaches and primary elements (Zhong, Schroder, Bekkering, 2021).

2.1 The concept and origins of the nature-based solutions

The prominence of the impact of the ecosystem on the human well-being has been always evident and reflected in beliefs and traditions of various societies from centuries. Ultimately in 1970 the idea of environmental or ecosystem services began to establish itself in the modern scientific literature. The necessity of systematic approach became more apparent in 1990, in order to document and reveal the relationship of human and nature. Many policies to promote the conservation, restoration and sustainable management of ecosystems as well as the consideration of increasing demands of ecosystem services are the result of 2005 Millennium Ecosystem Assessment being a residue of gradually growing awareness on the topic (Cohen-Shacham et al., 2016) .

The utilization of the term of Nature-based solutions dates back to the beginning of the 21th century. In the successive years, the Term was adopted by various worldwide institutions (Somarakis, G., Stagakis, S., & Chrysoulakis, N. Eds., 2019). The Term Nature-based solutions refers to people being not only the passive beneficiaries of nature's benefits but also refers to the capacity of humans to proactively protect, manage or restore natural ecosystems, in order to contribute to addressing certain major societal challenges.

In general the development of the NBS concept has been firmly grounded in global practice due to the fact that nature conservation and development sectors which previously were considered to have opposing objectives, have followed a common pathway to recognise positive and negative connections between human and nature. The advent and evolution of the sustainable development field is entirely a case in point. In addition, outlooks for nature conservation have broadened significantly, taking into account approaches that tackle the reasons of biodiversity decline such as loss of species habitats and pollution instead of a merely exclusive concentration on the protection of wilderness and wild and charismatic species. The ambitions for both biodiversity conservation and sustainable development are targeting the need to provide sustainable benefits for both people and the broader environment (Cohen-Shacham et al., 2016).

The NbS concept is increasingly being developed and applied by IUCN and other organisations, such as the European Commission (EC) and Wolrd Bank.The NBS concept has been promoted in 2009 position paper of IUCN on the United Nations (UN) Framework Convention on Climate Change (UNFCCC) COP 15. Moreover, in 2012 Nbs was formally adopted as one of the three areas of work within IUCN's 2013-2016 Programme.

The World bank has been also involved in milestones on the development of the concept of NBS.Biodiversity, Climate Change and Adaptation: Nature-Based Solutions from the World Bank Portfolio is a report for the World Conservation Congress in Barcelona in 2008. It is acting as an update of previous reviews of the World Bank biodiversity portfolio which was concentrated on specific ecosystems such as mountains, forests and Marine ecosystems and protected areas as well as previous overviews of the whole portfolio. The report contains useful data particularly on projects and programs that put an accent on linkages of biodiversity and climate change (World Bank 2008).

Efforts of international organizations, such as IUCN and the World Bank on searching solutions to work with ecosystems beyond relying on conventional engineering solutions (such as seawalls), with the aim of improving sustainable livelihoods and protection of natural ecosystems and biodiversity led to advent of the NBS concept in environmental sciences and nature conservation contexts (Mittermeier et al., 2008). The particular contribution of protected areas in responding to societal challenges such desertification and climate change has been also introduced through the concept of 'Natural solutions' which is following the same approach (Dudley et al., 2010).

Furthermore ,a catalogue of nature-based solutions for urban resilience by the World bank and the Global Facility for Disaster Reduction and Recovery (GFDRR) has been published in 2021. It suggests that despite of increased demand of NBS in Cities , the planners, investors and technical decision-makers for urban resilience have not yet the sufficient knowledge of building with nature. Consequently, it is a guideline for those who tend to shape urban resilience with

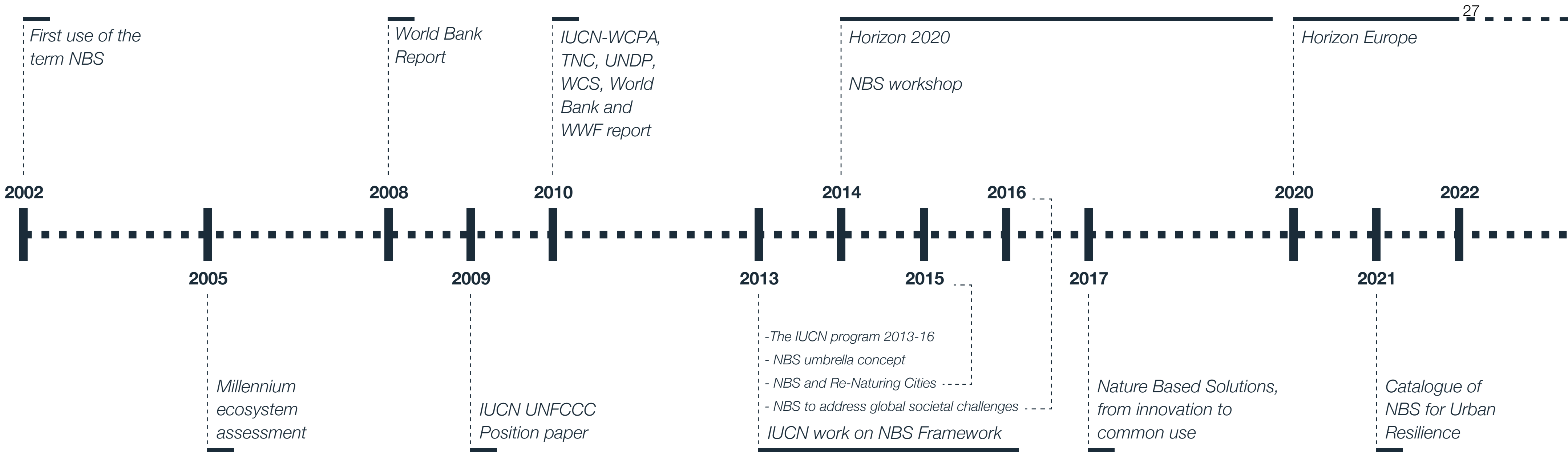


FIGURE 4:
Utilization of the term of NBS and development of its concept (Somarakis, G., Stagakis, S., & Chrysoulakis, N. Eds.. 2019)

nature, by discussing also some real-world case studies on how NBS approaches have worked in specific cases. Besides, it suggests that technical assistance is needed as well, in order to supporting more cities identify the specific feasible nature-based investments to address resilience challenges. (World Bank, 2021). Since 2013 NBS have been adopted as a term by the EC and has also been included as a part of the Horizon 2020 Research and Innovation Program of the EC, so as to promote synergies between nature, society, and the economy. EC is investing in a series of projects to strengthen the evidence base on NBS (Maes & Jacobs, 2015). An initiatives is the publication of a handbook dedicated to NBS, developed in the framework of the ThinkNature project in 2019. Its main objective is “to gather and promote state-of-the-art knowledge regarding NBS, comprising a comprehensive guide to all relevant actors.” It also supports the efficiency of NBS and their implementation through enhancing their replicability and upscaling. It proposes a comprehensive methodological approach for innovation as well. (Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). 2019).

2.1.1 The discussion of NBS definition in various literature

Nature-based solutions have been defined by various organizations and the definition is broadly illustrated and discussed in international literature during the previous years. The figure 2 demonstrates detailed information on the different interpretations of the NBS definition which are in fact sharing a great deal of similarity by aiming to address major societal challenges through the effective utilization of the ecosystem and its services.

The NBS definition developed by the European Commission consists of solutions which are inspired and supported by nature. In other words, the definition is beyond only the solutions which are utilizing nature (European Commission, 2015). Nature-based Solutions refer to any transition to utilization of ecosystem services with diminishing consumption of non-renewable sources and incrementing the investment in favor of renewable natural processes (Maes & Jacobs, 2015) . NBS are also considered as solutions to enhance and bring benefits in the sense of economic, social and environmental aspects while using the nature and ecosystem services (Zolch et al., 2017).

Source	Definition
Cohen-Shacham et al.(2016). [IUCN definition]	*'actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, simultaneously providing human well-being and biodiversity benefits'*
EC (2015).[EU definition]	*'solutions that are inspired and supported by nature, which are cost effective, simultaneously provide environmental, social and economic benefits and help build resilience'*
NBS initiative. [Oxford University]	*'involve working with nature to address societal challenges, providing benefits for both human well-being and biodiversity. Specifically they are actions that involve the protection, restoration or management of natural and semi-natural ecosystems; the sustainable management of aquatic systems and working lands such as croplands or timberlands; or the creation of novel ecosystems in and around cities. They are actions that are underpinned biodiversity and are designed and implemented with the full engagement and consent of local communities and Indigenous Peoples.'*
Kabisch et al.(2016).	*'is one of several concepts that promote the maintenance, enhancement, and restoration of biodiversity and ecosystems as a means to address multiple concerns simultaneously'*
Maes and Jacob (2015).	*'any transition to a use of ecosystem services with decreased input of nonrenewable natural capital and increased investment in renewable natural processes'*
Van de Bosch and Sang (2017).	*'solutions to societal challenges that are inspired and supported by nature which are cost effective, provide simultaneous environmental, social and economic benefits, and help build resilience'*
Frantzeskaki (2019).	*'living solutions underpinned by natural processes and structures that are designed to address various environmental challenges while simultaneously providing multiple benefits to economy, society and ecological systems.'*
Albert et al. (2019).	*'(i) alleviate a well-defined societal challenge, (ii) utilize ecosystem processes of spatial, blue and green infrastructure networks, and (iii) are embedded within viable governance or business models for implementation'*
Van der Jagt et al. (2017).	*'multifunctional 'green' interventions delivering upon the social, economic and environmental pillars of sustainable development'*
Zolch et al. (2017).	*'solutions using nature and ecosystem services to provide economic, social as well as environmental benefits and span from natural ecosystems to novel ecosystems that are either intentionally or unintentionally created by humans'*
UN World Water Assessment Programme (2018).	*'inspired and supported by nature and use, or mimic, natural processes to contribute towards the improved management of water. An NbS can involve conserving or rehabilitating natural ecosystems and/or the enhancement or creation of natural processes in modified or artificial ecosystems'*

2.1.2 An initiative framework to define the Nature-Based Solutions

The suggested framework developed by IUCN has been established due to the consultations with practitioners and scientists and it tends to enhance the functionality of the Nature-based solutions. With this regard, the overarching target of NBS is introduced to underpin reaching the development goals of the society and securing the human well-being taking into account the cultural and societal values and improving the ecosystems not only to be more resilient but also to enhance the ability of ecosystems to renew and supply their services. Food Security, water security, human health, climate change, disaster risk, and social and economic development are the main societal challenges to be addressed by Nature-based solutions (Cohen-Shacham et al., 2016).

In this framework, the Nature-based solutions are defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016). In this definition, the term ecosystem applies both to modified and natural ecosystems while the Term actions indicates and emphasizes the necessity of operative solutions to major societal challenges. In this context, the Term societal sheds light on the addressed targets of the nature-based solution, indicating them to be beyond environmental challenges and mitigation of environmental impacts. It is evident that NBS functionality requires a certain definition as well as a group of principles which are linked to its definition. (Cohen-Shacham et al., 2016) The eight principles are leading to a clear comprehension of nature-based solutions. In other words, the development of these principles was a supporting tool for IUCN and other institutions to create a common understanding of nature-based solutions (Cohen-Shacham et al., 2019).

According to the designated principles, the nature-based solutions include the nature conservation standards, this way emphasizing the fact that nature-based solutions are not intended to replace nature conservation, which still has a global prominence. However, the entire interventions in the direction of nature conservation are not considered to be

FIGURE 5:
The discussion of NBS definition in various literature

nature-based solutions. It is of note that nature-based solutions with the aim of addressing the major societal challenges can be applied both as a single option and combined with other solutions. Moreover, Each location has its specific natural and cultural features which embrace local, traditional and scientific knowledge and these characteristics have a significant role in the decision process for the nature-based solution for that specific site. Nature-based solutions are implemented to respond to an equitable distribution of societal benefits in a sense that supports transparency and participation in a wide range. Consequently, all types of stakeholders should be embraced by nature-based solutions. Preserving the diversity of biological and cultural aspects and the ability to the evolution of the ecosystems during the time should also be considered by the application of the nature-based solutions (Cohen-Shacham et al., 2019).

Noticeably, the application of the nature-based solution occurs also on the landscape level in many cases. Perhaps the large forests and watersheds are two brilliant illustrations of the phenomenon. In these contexts, there is the integration of a considerable number of ecosystems and this combination becomes transboundary in some cases. As a result, where nature-based solutions are applied at a specific site scale, it is still required to take into account the broader spatial level context with its own consequences with the aim of upscaling in case of necessity. Furthermore, the Compromissions and trade-offs between producing rapid economic interests for the development and future choices for the production of the entire ecosystem services should be recognized and addressed by Nature-based solutions. That is to say that nature-based solutions should refrain from any alteration or simplification of the ecosystem with the aim of supporting a specific resource or service. The approach to the determinations among various NBS activities should be based on a detailed comprehensive of trade-offs between today's interests and the future benefits. In addition, Addressing a specific challenge requires the design of policies, actions or measures and nature-based solutions are an inseparable ingredient of their general design.

2.2 Typologies of Nature-Based Solutions

A typology to characterize nature-based solutions according to the level of involvement of engineering biodiversity and ecosystems along with the the amount of the engagement of ecosystems and stakeholder by a given NBS has been proposed as a result of the analysis carried out by BiodivERsA ERA-NET. BiodivERsA is a network consisting of 32 agencies and ministries from 21 EU countries with the objective of programming and funding pan-european research on biodiversity and ecosystem services. It is an ERA-NET Co-fund, funded under the EU's Horizon 2020 Framework Programme for Research and Innovation. According to the analysis, generally higher numbers of targeted services and stakeholder decrease the feasibility to maximize the delivery of each service and at the same time to reach a total response to the specific needs of all stakeholder groups.

The proposed Typology by BiodivERsA ERA-NET consists of three main types of NBS:

Type 1: these are the solutions with the objective of more efficient utilization of existing natural and protected ecosystems by applying no or minimum intervention on them. For instance, enhancing fish stocks in an intact wetland to improve food security is a vivid illustration of this type.

Type 2: solutions that apply management approaches to develop sustainable and multifunctional ecosystems and landscapes. The management that has the capacity to enhance the delivery of a chosen NBS in comparison to a more conventional intervention scenario for the same NBS.

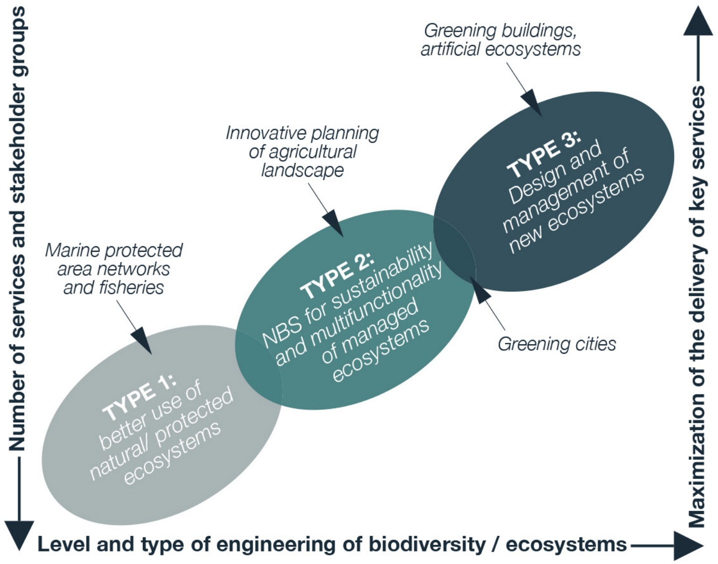


FIGURE 6:
The main types of the nature-based solution according to the implementation level of management and engineering (Eggermont et al., 2015, Cohen-Shacham et al., 2016)

Type 3: these solutions embrace creating new ecosystems. Constructing green buildings with green walls and roofs to mitigate the warm temperature in cities and ameliorating the air quality is a case in point.

The proposed Typology creates the possibility to distinguish and categorize the broad range of NBS approaches into different groups taking into account the common features in order to frame the NBS concept considering the sorts of approaches that would classify as NBS. (Eggermont et al., 2015, Cohen-Shacham et al., 2016). These typologies are illustrated in the figure 4.

2.3 NBS as an umbrella concept

NBS can be considered as an umbrella concept for a range of ecosystem-related approaches. These approaches are designated to respond to specific or multiple societal challenges, being distinguished into five main categories. At the same time, these approaches are providing human well-being and biodiversity benefits.It is of note that most of the ecosystem approaches have been introduced before the advent of the NBS meanwhile they generally fulfill the definition of the NBS. Furthermore, the types of addressed ecosystem services and involved interventions are vividly illustrating the similarity between NBS and various ecosystem approaches. The ecosystem approaches are clustered under NBS as the overarching concept. These approaches can also propose a conceptual foundation on which an operational framework for NBS can be built. The future development of NBS is substantially due to this conceptualisation (Cohen-Shacham et al., 2016).

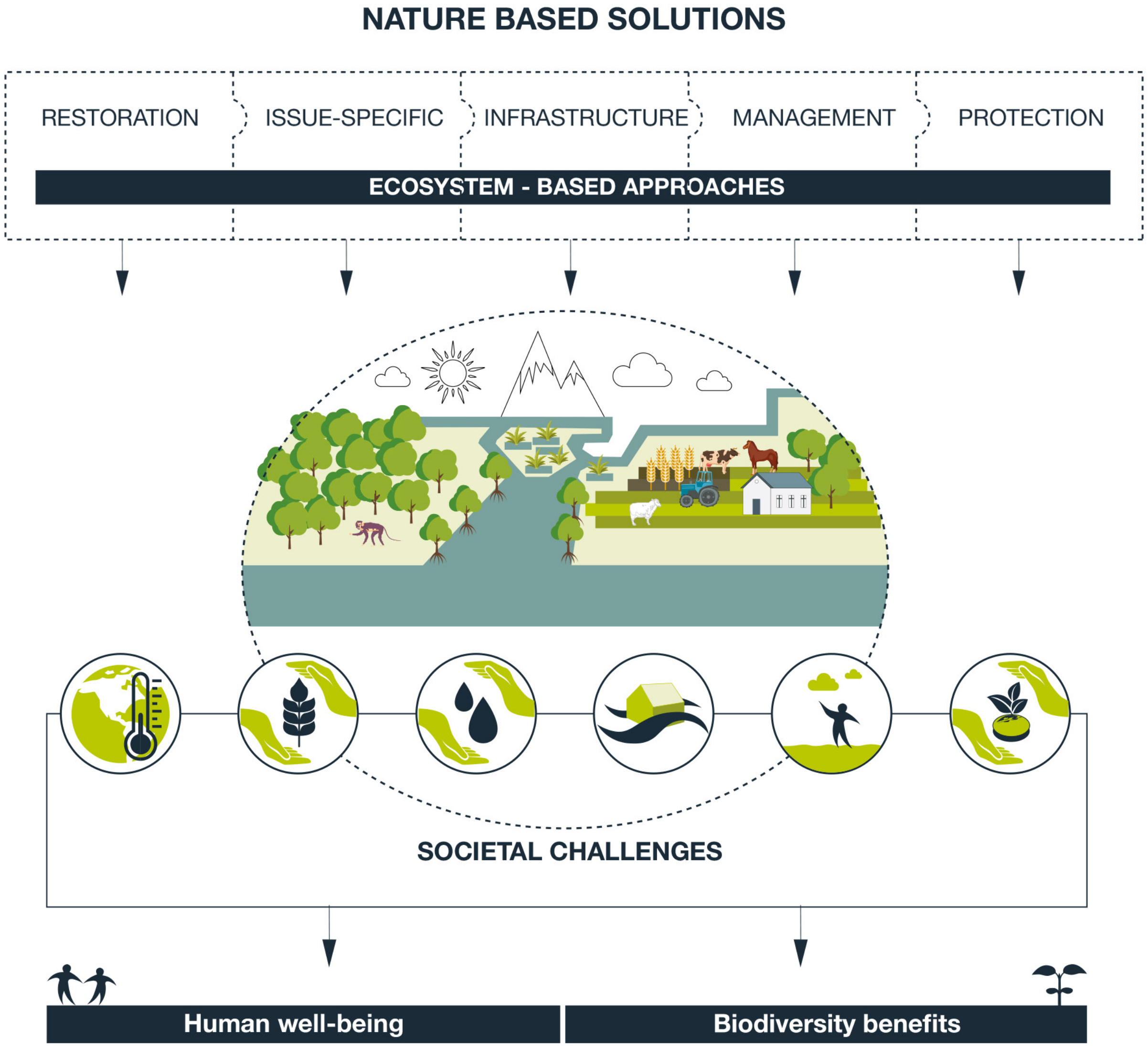
2.3.1 Ecosystem-related approaches as NBS

Ecosystem-related approaches which are appearing as NBS are divided into 5 categories.

Category 1: Restoration (Ecological restoration, Ecological engineering, Forest landscape restoration)

An ecological study of habitats and species precedes the ecological restoration (ER). The acquired information leads to a conscious restoration of the

FIGURE 7:
Representation of the umbrella concept of NBS for the Ecosystem-related approaches (Cohen-Shacham et al., 2016)



ecosystem and conservation of biodiversity (Hobbs et al., 2011) . Ecological engineering (EE) is also strongly related to ecological restoration (Mitsch, 2012). However, it simultaneously embraces ecology and engineering (Schulze, 1996). Ecological engineering is applicable at all scales (Gosselin, 2008).

Forest landscape restoration (FLR) refers to "the ongoing process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. FLR is more than just planting trees – it is restoring a whole landscape to meet present and future needs and to offer multiple benefits and land uses over time." (IUCN). It is evident that FLR does not act as a simple restoration tool since its scope is to restore the ecological health, ameliorate human well-being and lead a previously degraded landscape to a long term resilience.

Category 2: Issue-specific (Ecosystem-based adaptation(EBA), Ecosystem-based mitigation(EBM), Ecosystem-based disaster risk reduction(Eco-DRR) , Climate adaptation services(CAS))

EbA as a term, was introduced in 2008 during the UNFCCC COP 14 by IUCN.(Rizvi et al., 2014).

In 2009 CBD came up with an official definition which later in 2010 was updated to " sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities" (CBD, 2010). EBA can be implemented on various scales but it acts more efficiently on a local level (Locatelli et al., 2011; Rizvi, 2014) . Both EBA and EBM are approaches to provide the ecosystem with unobstructed functionality as well as ensure human health and socio-economic security due to storing carbon. The Reducing Emissions from Deforestation and forest Degradation+ (REDD+) is a programme adopted by UNFCCC that tends to bridge mitigation and adaptation (UNFCCC, 2008).

The objective of the concept of Climate Adaptation Services (CAS) is to develop the choices of adaptation to climate change. CAS is broader in comparison to EBA, because it also considers the ecological mechanisms and characteristics that influence the capacity of the ecosystem to adapt and resist changes (Lavorel et al., 2015).

The Ecosystem-based disaster risk reduction (Eco-DRR) improves the capacities of the people so as to reach better management and recovery from the impacts of the hazards. As a consequence, it diminishes the effects of the hazard events. Eco-DRR approach is distinct from EBA and EBM, since it also takes into account hazard events other than the ones correlated with climate change and climate variability (Renaud et al., 2013).

Category 3: Green infrastructure(GI) and Natural infrastructure(NI) approaches

In the context of the EU green infrastructure strategy, the Green infrastructure is defined as: "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" by the European Commission (European Commission, 2013). Restoration of the structure, function and composition of the ecosystem to be capable of delivering the ecosystem services is more related to a NI approach. In contrast, a GI approach delivers ecosystem services by ameliorating the same aspects of the ecosystem. GI approach can be utilized at an urban as well as a landscape level, while a NI approach is useful only for the landscape level. However, it is of note that GI and NI have many common principles and aims that cover connectivity, smart conservation and multifunctionality.Moreover, hard infrastructure and ecosystem-based infrastructure are presented as blended solutions in both NI and GI approaches (European Environment Agency, 2011).

Category 4: Ecosystem-based management (EbMgt) approaches)

The application of Ecosystem-based management is significantly common in the contexts of ecological and environmental management. Management plans, or specific legal tools that designate multiple utilization of the coastal marine protected areas are a vivid illustration of the tools that can enhance the application of an ecosystem-based management approach (Cárcamo et al., 2013).

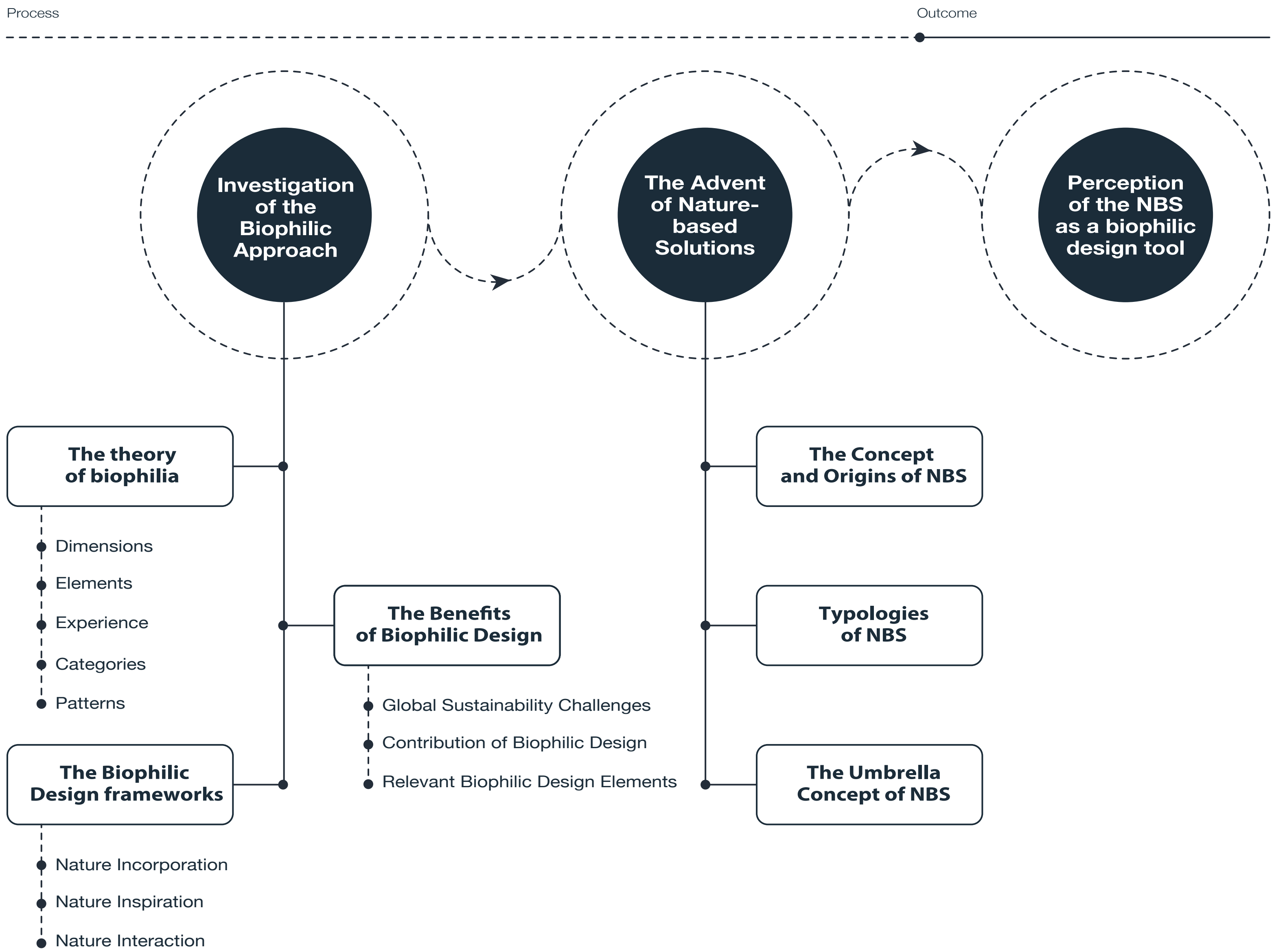
Category 5: Protection (Area-based conservation approaches, that also covers the management of protected areas along with other measures to support the area-based conservation).

The main scope is to conserve biodiversity and geodiversity and introduce ecosystem services without being in contradiction with nature conservation (Dudley, 2008).

2.3.2 NBS response to societal challenges

Modern societies are prone to various challenges. In this regard, NBS have the capability to address some priority areas such as Water security, food security, human health, disaster risk reduction and climate change (Cohen-Shacham et al., 2016). NBS also targets aspects such as regeneration and well-being in urban areas, carbon sequestration, coastal resilience, watershed management and ecosystem restoration which are related to the initially noted areas.

Moreover, topics such as NBS to enhance the insurance value of ecosystems and to foster sustainable use of matter and energy are a step forward in the NBS role in addressing the societal challenges (European Commission, 2015).



Process
Outcome
Investigation of the Biophilic Approach
The Advent of Nature-based Solutions
Perception of the NBS as a biophilic design tool
The theory of biophilia
Dimensions
Elements
Experience
Categories
Patterns
The Biophilic Design frameworks
Nature Incorporation
Nature Inspiration
Nature Interaction
The Benefits of Biophilic Design
Global Sustainability Challenges
Contribution of Biophilic Design
Relevant Biophilic Design Elements
The Concept and Origins of NBS
Typologies of NBS
The Umbrella Concept of NBS

CHAPTER 3
NBS AND THE BUILT ENVIRONMENT

3. Nature-Based Solutions and the Built Environment

Following a growing tendency during the recent decade, currently 71.04% of people in Italy live in urban areas (Statista 2020). Rapid urbanization and sprawl of cities along with the impacts of climate change may lead to several severe issues if not managed properly. Reduced air quality, mismanagement of flooding water and water pollution, excessive noise, urban heat island and extreme urban temperature are some of the problems that may be caused and result in descending livability of the cities, being incapable of providing a response to climate change, urban biodiversity, human health and wellbeing.
Following international climate change negotiations, particularly the Paris agreement (2016), Long Term Low Emission Development Strategies (LT- LEDS) have been developed, addressing the parties, national policy-makers and other decision-makers to meet the mid-century climate goals. There is potential for these long-term strategies to guide short and mid-term action and substantially shape the National Climate Plans (NDCs), short- and mid-term priorities, policies and investment pipelines (Falduto, Rocha, 2020).

A more recent approach of the international community has diversified its efforts, previously with a narrow focus on limiting CO2 emissions to promoting climate change adaptation and mitigation policies. These complementary strategies with a wide range of challenges aim to assist achieving a minimum effect of this widespread phenomenon. The difference between these two is that mitigation is addressed to tackling the causes and deducing the impacts of climate change, while adaptation suggests strategies to diminish the negative effects it has and look for possible solutions to take advantage of arising opportunities.
Urban climate change adaptation and mitigation plans are simultaneously developed to make progress toward enhancing climate resilience. While there is consensus on the necessity of focusing on both for efficient results, better understanding of their interactions is required to identify their potentials. The diagram below demonstrates an idea about the different categories of measures which provide adaptation and mitigation co-benefits (Sharifi 2020).
In this context, the effective implementation of NBS

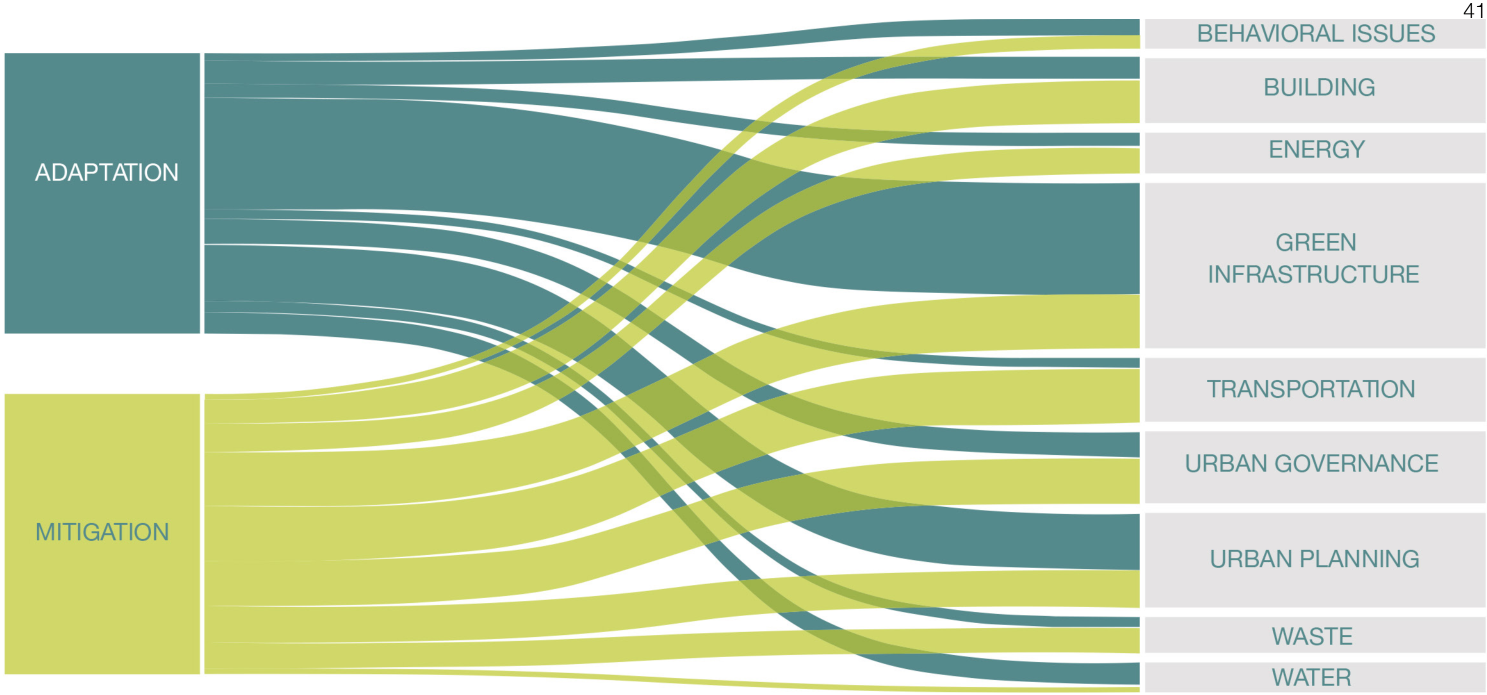


FIGURE 1:
Various types of strategies contributing to adaptation and mitigation co-benefits (Sharifi 2020).

in various sectors, including urban and building scale, can help tackle climate change impacts with an outstanding potential for climate adaptation and mitigation, (Frantzeskaki, McPhearson, Collier, Kendal, Bulkeley, Dumitru, Walsh, Noble, Wyk, Ordóñez, Oke, Pintér, 2019) at the same time positively influencing the urban environment, human health and wellbeing in order to ensure a sustainably developing urbanization and deliver social, ecological and economic benefits (Lafortezza, Chen, van den Bosch, Randrup, 2018) (Raymond, Frantzeskaki, Kabisch, Berry, Breil, Nita, Geneletti, Calfapietra, 2017).

3.1 Climate Change Mitigation

Climate change mitigation is defined as actions to limit global warming and its related effects. The term "mitigation" is referred to reducing climate change, involving reduction of the heat-trapping greenhouse gasses flow into the atmosphere, either by reducing sources of these gasses or enhancing the "sinks" that can accumulate and store them, such as the oceans, forests and soil.

The aim of mitigation is to prevent human interference with the climate system (UNFCCC 2002), and "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (IPCC, 2014).

There is considerable evidence that some NBS can have a role to play in mitigating climate change through carbon capture and storage and reducing carbon emissions by means of insulation systems and temperature control measures.

Therefore, it is possible to define two main aspects to contribute to mitigation of climate change impacts through implementation of NBS in the built environment:

- Reducing the energy consumption by applying insulation measures and reducing the environmental temperature.
- Carbon sequestration

3.1.1. Reduction of Energy Consumption and Carbon Sequestration

Currently a significant proportion (25%) of greenhouse gas emissions driving from human activities are associated with burning fossil fuels for electricity and heat production (IPCC, 2014). This amount is mainly addressed to heating and cooling the buildings, which means that providing appropriate external and internal protection and insulation means can be effective to reduce the amount of consumed energy and the consequent impact.

The importance of cooling urban areas is remarkable due to the Urban Heat Island effect (UHI). UHI is defined as an urban or metropolitan area that is notably warmer than its surrounding rural areas due to human activities. The temperature difference or the UHI intensity is usually larger at night than during the day, and is more noticeable during summer and winter. In Turin for instance UHI is more evident during the night in spring and summer, about 4°C. In fall it is reduced to 2°C at night and almost 0 from 10AM to 5PM, while in winter the 2°C temperature difference is extended all day long (Milelli, 2016). More details are represented in the Environmental analysis in chapter five.

Energy Saving and Carbon Sequestration Due to Land Use Management, Regenerating Brownfields

Modification of land surfaces is one of the main causes leading to UHI in cities. It is due to the gradual development of urban infrastructure and the built environment integrated with human activities often resulting in creation of brownfields.

The term “brownfield” refers to a land which has previously been developed, it covers contaminated, vacant or derelict land or land occupied by an unused building, such as former industrial and commercial areas, or decommissioned landfills which have become a part of urban fabric due to sprawl. Apparently, brownfields have a great potential to act as NbS for carbon sequestration, with possibility to be combined with other interventions to achieve multi-functionality.

Brownfields are considered attractive properties for redevelopment. Taking the fact that these are usually available for a below market price, local governmental policies for taxes and environmental protection may increase the interest of the investors. According to Michael McLaughlin, vice president of SCS Engineers, “Brownfields are not environmental projects—they’re real estate projects with an environmental twist”.

It is crystal clear that the potential of regenerating brownfields varies according to various factors such as the actual dimensions of the site and required level of interventions in order to remediate the site in case of contamination. However, it is worth mentioning that not all brownfields are contaminated, and those which are considered so, are subjected to remediation after being diagnosed. Considering the contamination type the site can undergo a cleaning and be prepared for use. Some common contaminants are heavy metals or volatile organic compounds (VOCs), while bioremediation, phytoremediation, soil washing and use of nanotechnology are among the techniques for remediation (Seward2012). Details related to the subject of this research will be represented in the Environmental analysis in chapter five.

Brownfields, therefore, remain a potential source for implementation of NBS in the built environment. Revitalized simply as a community park or a multifunctional transite space, these abandoned lands have a notable role to play in development strategies, acting as new lungs and recreational space for cities. Besides aesthetic improvement, the revitalization of brownfields can assist in managing numerous urban climate change risks such as flood control and air quality, while enhancing biodiversity, health and wellbeing in urban areas, benefiting simultaneously human and nature.

Energy Saving and Carbon Sequestration Due to Urban Green

There is considerable evidence that implementation of green infrastructure in urban areas can help in mitigating climate change. Urban nature may appear in various forms being urban trees, green walls, green roofs, green spaces and sustainable drainage systems (SuDS), all associated with the delivery of many beneficial ecosystem services.

In urban environments, NBS can be helpful in cooling the surrounding air temperature, reducing cooling energy demands within the surrounding buildings. Vegetation layers applied to buildings are acting as shaders for the heat-storing surfaces and contribute to cooling by absorbing solar radiation, and through evaporation and evapotranspiration. Apparently, green walls can support 8-15% total energy savings for the space directly behind the green wall, and green roofs about 7% total energy savings for the space directly below the green roof.

Street trees, parks and green spaces reduce the temperature of the surrounding air as well and can reduce cooling requirements in adjacent buildings, resulting in lower energy costs. Buildings protected by shade trees can save over 30% of residential peak cooling demand for conditioning systems (Zardo, Geneletti, Pérez-Soba, Van Eupen, 2017).

Alongside their climate adaptation and biodiversity benefits, NBS can be beneficial also through carbon capture and storage. The sequestration capability of plants and soil varies depending on the planting system, substrate depth, applied species, and further management. Therefore, it is crucial for the plant species to be chosen and located with acknowledgment to local conditions to ensure a long, productive life (Nowak, Stevens, Sisinni, Luley, 2002), and be evaluated according to the future climate resilience as well (Roloff, Korn, Gillner 2009). Furthermore, it would be more effective, to eliminate or minimize the fossil fuel consumption for the maintenance activities, in order to optimize the results (Davies, Edmondson, Heinemeyer, Leake, Gaston, 2011). Regarding the carbon amount sequestered and stored by NBS in urban environments, apparently, Green walls, Green spaces, Green roofs and SuDS are capable of sequestering 0.68kg, 0.2kg, 1.28kg, 0.27kg carbon per m^2yr respectively. At the same time Green spaces, Green roofs have 1.01kg, 0.375kg and 3.05–5.04kg carbon storage capacity per m^2. Similarly, urban trees are able to sequester 0.68kg carbon per m^2yr, with 231.6kg carbon storage capacity per tree. Therefore, application of NBS in the built environment can be outstandingly influential on the reduction of carbon emissions by providing insulation and temperature control.

3.2 Climate Change Adaptation

As a complementary strategy for climate change mitigation, adaptation is another way to respond to climate change. It refers to adapting to life in a changing climate, adjusting to actual or expected future climate, aiming to reduce the vulnerability to the harmful effects of climate change and to benefit from the potential beneficial opportunities associated with climate change. The Intergovernmental Panel on Climate Change (IPCC) has defined “Adaptation” as the process of adjusting to current or expected effects of climate change, identifying two variations of actions: incremental and transformative. The incremental actions aim to maintain the essence and integrity of a system, while the transformative ones change the fundamental attributes of a system in response to climate change and its impacts.

IPCC has also categorized the adaptation actions in three distinct categories, namely: Structural and physical adaptation, Social adaptation and Institutional adaptation. The first category represents the actions related to the built environment, technology and ecosystem-based services, the second refers to educational, informational, behavioral actions, and the third deals with economy, regulations, government policies (Noble, Huq, Anokhin, Carmin, Goudou, Lansigan,Osman-Elasha, Villamizar, 2014). There is no doubt that depending on sensitivity and vulnerability level, the adaptation approaches may be different. However, there are some common aspects related to climate change adaptation in the built environment:

- Urban Hydrology: water management, capture, storage and reuse
- Cooling the city: protection against heat waves and extreme heat
- Improving the air quality
- Food production

3.2.1. Urban Hydrology: Water Management, Capture, Storage and Reuse

In recent years there is an increasing trend for the impact of flooding due to the increased rainfall associated with climate change. Adaptation of the existing water infrastructure in order to deal with increased rainfall amount requires high costs and time associated with maintenance and installation. Therefore, implementation of NBS and a network of inter-connected engineered devices integrated into gray infrastructure can be a cost effective solution for stormwater management in the built environment (Ashley, Horton, Lavers, McLaughlin, 2017). Engineered devices include components such as rain gardens, permeable pavements, swales and wetlands, and are designed to mimic natural drainage processes aiming to manage surface water and flood risk as well as providing biodiversity and amenity benefits.

NBS creates more porous surfaces on the buildings and surrounding environment. Urban parks and green spaces, forests, wetlands, green roofs and engineered stormwater treatment devices can be effective to capture and slow the rate of the runoff by increasing infiltration and water storage.

Application of NBS can also reduce the surface flooding and contamination of runoff by pollutants on the roads in urban areas. NBS is a potential strategy also for river flood integrated in urban context, although it is more effective in cities with less or no gray flood-mitigation infrastructure. Creating permeable areas and engineered devices, developing vegetation coverage along the river can help to manage the floods and reduce flood peaks.

Apparently, cities adopt various types of adaptation and regulatory mechanisms for flood risk management. With a well organized water management system cities will be able to provide resilient water supply. Alongside the different forms of NBS and engineered devices, there are additional sources of water available to replace the water supplied by NBS, such as rainwater harvesting, inter-basin transfers, or desalination plants. Although the water sourced by NBS is economically and energetically more efficient than reusing potable water, rainwater harvesting turns out to be even more efficient (Drosou, Soetanto, Hermawan, Chmutina, Bosher, Hatmoko, 2019).

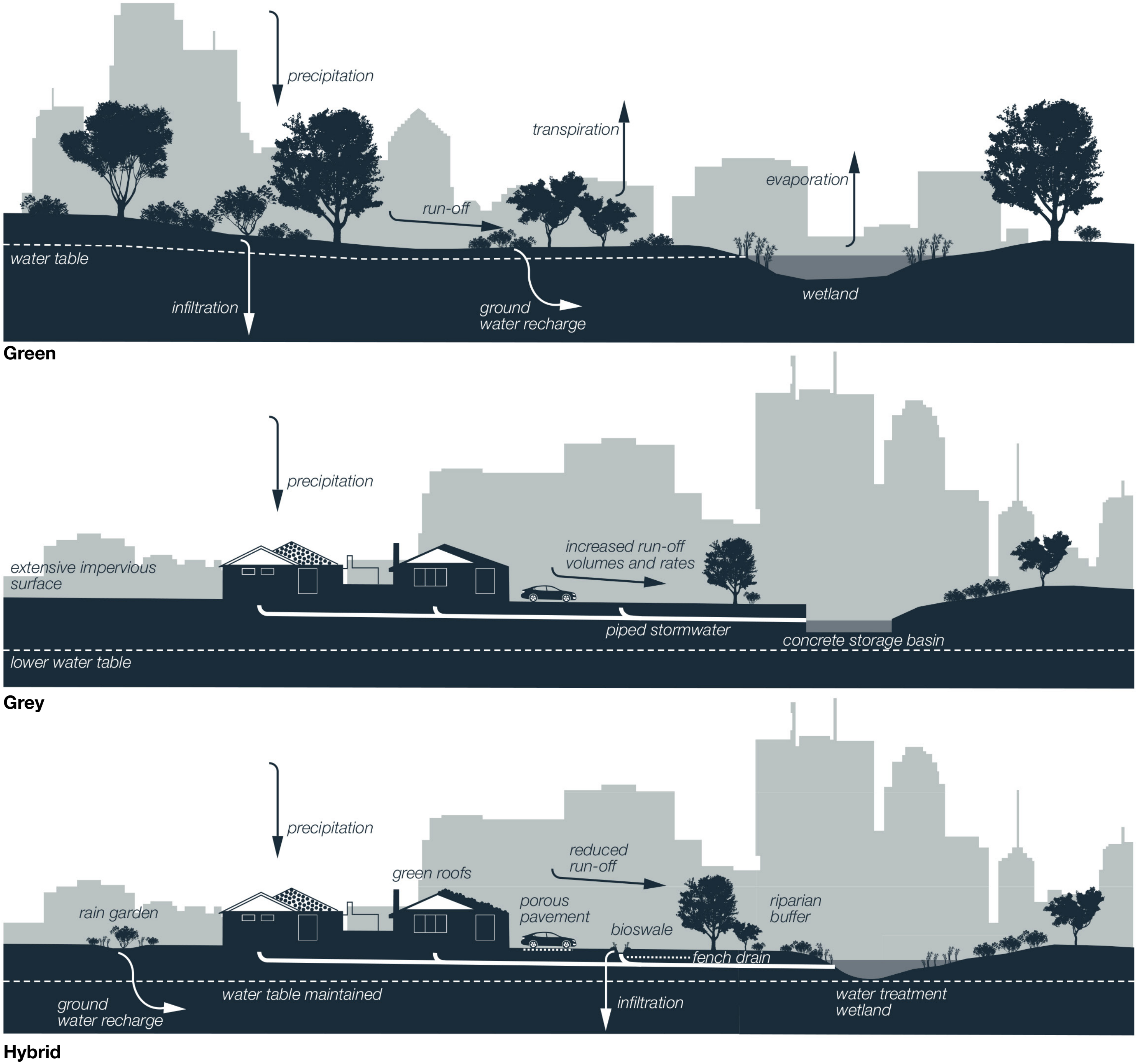


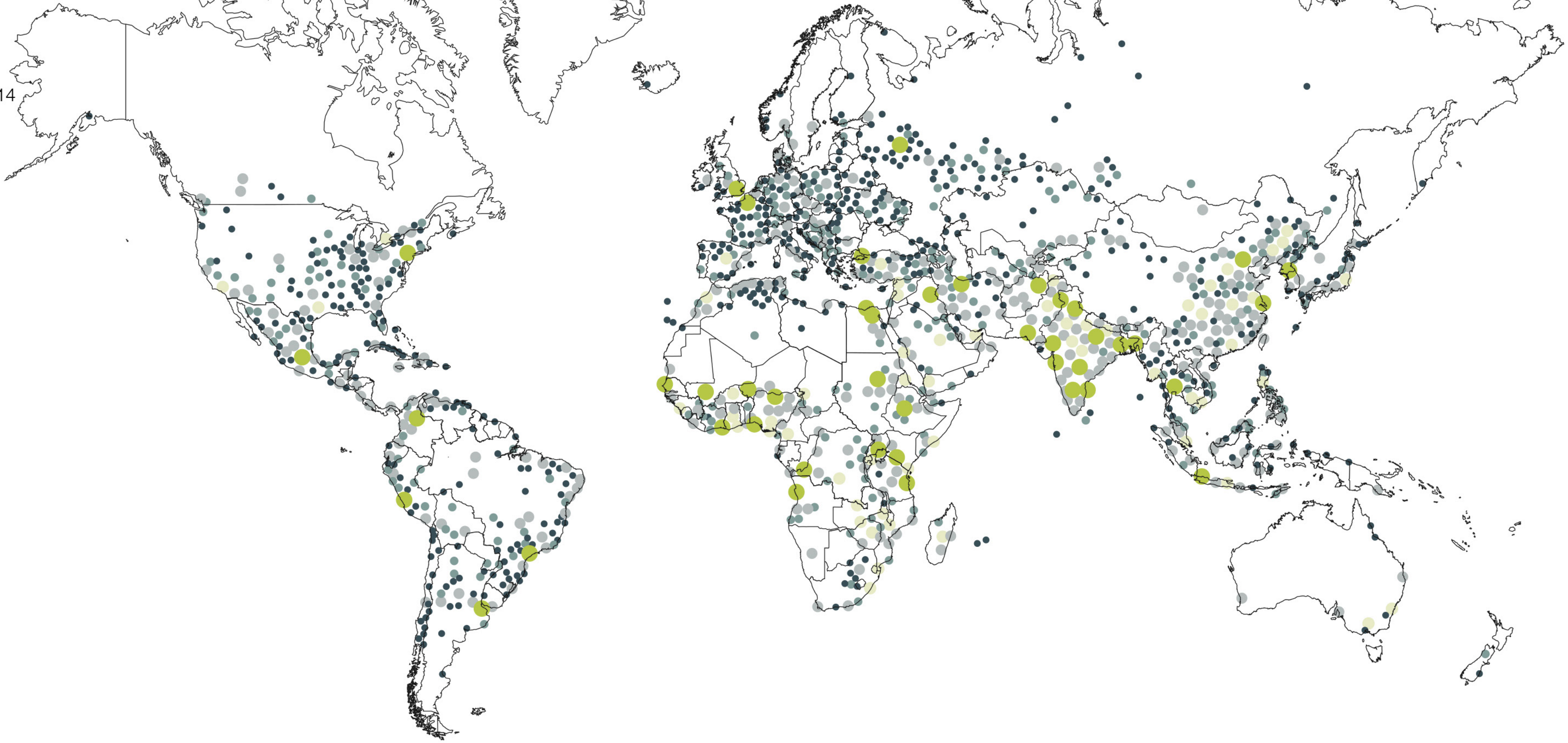
FIGURE 2:
Green, grey and combined approaches to maximize water absorption in urban areas. (Depietri, McPhearson, 2017)

3.2.2. Cooling the City: Protection Against Heat Waves and Extreme Heat by Regulating the Temperature.

During the recent decades heatwaves have caused serious impact both on human wellbeing and biodiversity. If climate action is not taken this trend is likely to worsen with increasing number and length of heatwaves, estimated 2°C increase of temperature by mid century and about 4°C by 2100. Figure 3 illustrates the map of cities experiencing three month average 35°C in 2050s (UCCRN, 2018).

Implementation of NBS in the built environment which includes public and private spaces and various dimensions of built structure is expected to reduce the negative impact. Urban cooling and reduction of the mean radiant temperature and extreme temperatures during heat waves by NBS acts due to several mechanisms such as shading and evapotranspiration. Implementation of these mechanisms are due to greater density and more canopy coverage compared to other built and paved surfaces. Overall, urban green and blue infrustructures are able to regulate the outdoor temperature, mitigate the UHI and provide outdoor human thermal comfort, slightly influencing also the indoor temperature (Coutts, White, Tapper, Beringer, Livesley, 2016). Additionally, protection against urban heat by NBS can lead to improvements in the longevity and quality of a site's assets extending the lifespan of the structure.

Among the urban green solutions, street trees can provide shaded avenues and improve the local cooling benefits. Planting trees especially in areas with high heat vulnerability risk can be significantly effective, reducing the surrounding air temperature and adjacent indoor temperature by 3°C. Creating urban green spaces can provide cooler hubs integrated in urban fabric for various purposes. Compared with other paved surfaces, green spaces can reduce daytime air temperature by 2.7°C in urban areas. Green walls and roofs act as a heat-absorbent external layer creating an outstanding difference both on interior and exterior temperature. Green walls are reported to cause 1-4°C reduction in surrounding air temperature and 3-5°C reduction in indoor temperature, while this amount for green roofs is 1-2°C reduction in surrounding air temperature and 2-4°C reduction in indoor temperature.



There is enough evidence that widespread application of NBS has the potential to impact the regional heat profile of cities. However green spaces less than 0.5-2.0 ha may have negligible cooling effects at regional scales. In this case shading strategies have more evident cooling benefits (Bevilacqua, Mazzeo, Bruno, Arcuri, 2017). At the same time, successful urban cooling depends also on the specific characteristics of the city, including the geographic, climatic and ecological aspects, urban shape and existing greenery, as well as other technical, social and governmental factors.

FIGURE 3:
Urban Population Centres experiencing 3-month average 35 degrees in the 2050s. Source: UCCRN, 2018: 13 © UCCRN.

LEGEND

- *10.000.000+*
- *5.000.001 - 10.000.000*
- *1.000.001 - 5.000.000*
- *500.001 - 1.000.000*
- *100.000 - 500.000*

3.2.3. Air Quality

Air pollutants are a significant risk factor for the air quality in urban areas. These are the contamination of air due to the presence of substances in the atmosphere, generated both by human activity and natural processes, that are harmful to humans, wildlife and the environment. Carbon dioxide and nitrogen dioxide are recognized as the main air pollutants, while there are other climate-sensitive air pollutants such as the ground level ozone and aeroallergens. Increasing temperature can affect the chemistry and chemical reactions associated with these pollutants creating secondary pollutants as well. Human exposure to these substances, particularly the ground-level ozone and particulate matter, increases the risk of various severe diseases and mortality (WHO 2014). Other living organisms can also be affected and damaged by Air pollutants. Presence of pollutants in the natural environment can be destructive and lead to climate change, ozone depletion and habitat degradation. Moreover, the consequences related to above mentioned phenomena such as acid rain can be harmful for the built environment as well. Therefore, it is crucial to investigate and provide appropriate solutions in order to fulfill the air quality requirements in the affected areas. Regarding these concerns several norms and standards have been developed to set pollutant concentrations thresholds that shall not be exceeded in a given period of time.

EU air quality standards and the World Health Organization (WHO) guidelines are summarized in the figure 4, applying over differing periods of time in order to observe health impacts associated with the various pollutants over different exposure times. The European Environment Agency has reported a 25% reduction in NO2 annual mean concentrations in major cities in France, Italy and Spain, during the 2020 lockdowns, while Ozone levels were lower than in previous years as well. However, air pollution is still a major health concern for Europeans, despite these reductions, with 96% of the urban population exceeding the limits of exposure to fine particulate matter set by the World Health Organization (WHO). Italy and Central-eastern Europe have reported the highest concentrations of particulate matter, due to the burning of solid fuels for domestic heating

		EU AIR QUALITY DIRECTIONS			WHO AIR QUALITY GUIDELINES					
Pollutant	Averaging Period	ObjectiveC	oncentration	CommentsC	oncentration Interim targets 1.	2.	3.	4.	AQG level	Comments
$PM_{2.5}$	24-hour	Target Value		Not to be exceeded on more	75	50	37.5	25	$150_{\mu g/m3}$	99th percentile (i.e. 3-4
$PM_{2.5}$	Annual	Limit Value	$25_{\mu g/m3}$	than 35 days/year	35	25	15	10	$5_{\mu g/m3}$	exc. days/year)
$PM_{2.5}$	Annual	Limit Value	$20_{\mu g/m3}$							
$PM_{2.5}$	24-hour	Limit Value	$50_{\mu g/m3}$		150	100	75	50	$45_{\mu g/m3}$	99th percentile (i.e. 3-4
$PM_{2.5}$	Annual	Limit Value	$40_{\mu g/m3}$		70	50	30	20	$15_{\mu g/m3}$	exc. days/year)
O_3	Max daily 8h mean	Target Value	$120_{\mu g/m3}$	Not to be exceeded on more						
O_3	Max daily 8h mean	Long-Term	$120_{\mu g/m3}$	than 25 days/year (average						
O_3	8-hour	Target Value		over 3 years)	160	120	-	-	$100_{\mu g/m3}$	99th percentile (i.e. 3-4
O_3	Peak season	Target Value			100	70	-	-	$60_{\mu g/m3}$	exc. days/year)
NO_2	Hourly	Limit Value	$200_{\mu g/m3}$	Not to be exceeded on more					$200_{\mu g/m3}$	
NO_2	Annual	Limit Value	$40_{\mu g/m3}$	than 18 hours/year	40	30	20	-	$10_{\mu g/m3}$	99th percentile (i.e. 3-4
NO_2	24-hour	Target Value			120	50	-	-	$25_{\mu g/m3}$	exc. days/year)
SO_2	Annual	Limit Value	$350_{\mu g/m3}$	Not to be exceeded on more						99th percentile (i.e. 3-4
SO_2	Annual	Limit Value	$125_{\mu g/m3}$	than 24h/year, 3days/year	125	50	-	-	$40_{\mu g/m3}$	exc. days/year)
CO	Annual	Limit Value	$10_{mg/m3}$						$10_{mg/m3}$	99th percentile (i.e. 3-4
CO	Annual	Target Value			7	-	-	-	$4_{mg/m3}$	exc. days/year)
C_6H_6	Annual	Limit Value	$5_{\mu g/m3}$	Measured as content in PM_{10}					$1.7_{\mu g/m3}$	Reference level
BaP	Annual	Target Value	$1_{ng/m3}$							
Pb	Annual	Limit Value	$0.5_{\mu g/m3}$						$0.5_{\mu g/m3}$	
As	Annual	Target Value	$6_{ng/m3}$	Measured as content in PM_{10}					$6.6_{ng/m3}$	Reference level
Cd	Annual	Target Value	$5_{ng/m3}$						$5_{ng/m3}$	
Ni	Annual	Target Value	$20_{ng/m3}$						$25_{ng/m3}$	Reference level

FIGURE 4:
Air quality directions and guidelines by EU and WHO (European Environment Agency)

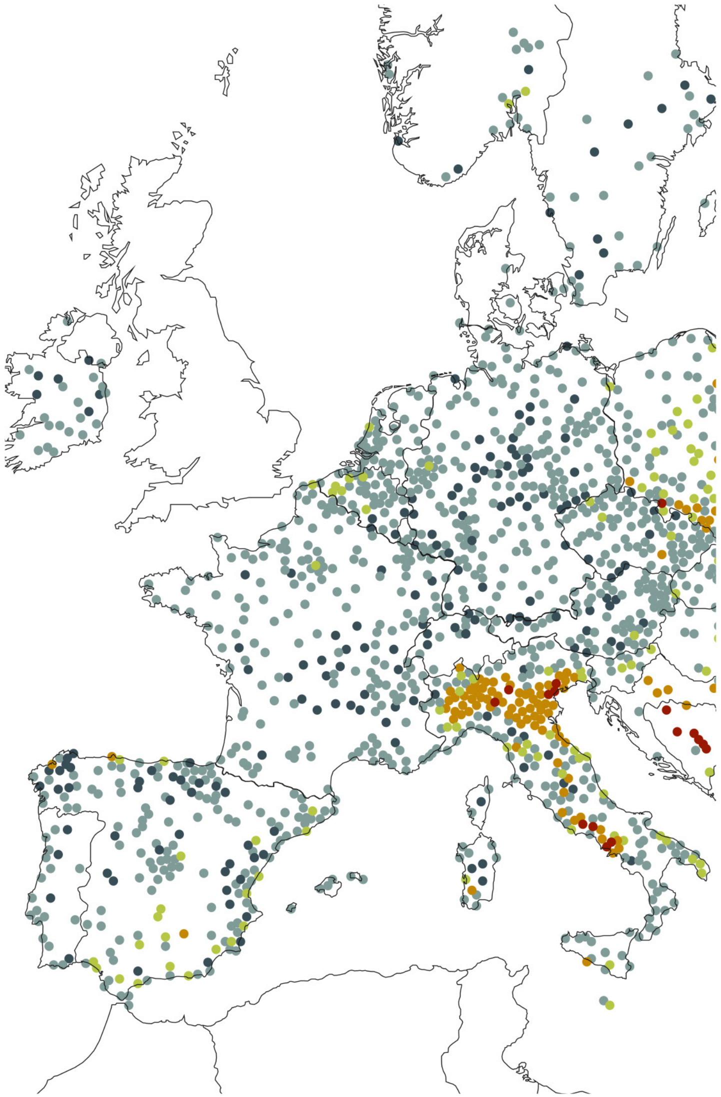


FIGURE 5:
pm 10 concentration during 2020 and 2021 in relation to the daily limit value set by EU. Source: European Environment Agency Unit µg/m³

LEGEND

- *>75*
- *>50 and <=75*
- *>40 and <=50*
- *>20 and <=40*
- *<=20*

and industrial use. (figure 5)
NBS in cities can be helpful to regulate air quality by absorbing air pollutants. Vegetation and trees are able to absorb airborne particulate matter (PM), ultrafine particles (UFP) contributing to the toxicity of PM and other emissions, sequester carbon dioxide and positively affect ground-level ozone. However, the selection of plant species is extremely important in this context. Certain vegetation species emit significant amounts of reactive biogenic volatile organic compounds (VOCs), which can be harmful for ozone formation. Therefore, species with low VOC emissions, low allergen emissions, and high pollutant deposition potential are recommended, in order to obtain the maximum benefit from the NBS for improving air quality in the built environment. It is worth mentioning that the positive results are obtainable only in the presence of combined strategies for the reduction of emission sources such as transportation.
The data related to the air quality and relevant pollutants in Turin are represented in the environmental analysis of chapter five.

3.2.4 Food Production and Security

Around 795 million of the global population, prevalently living in developing countries are estimated to be undernourished (FAO, IFAD, WFP, 2015). Consequently, food security remains one of the major societal challenges. Urbanization, the increase in global population and the changes in the nutrition of the people are significantly related and lead to the issue of feeding the people to be one of the major societal challenges in an urbanizing world during the last decades (Godfray et Al, 2010). Food and nutrition security concerns all the people at all times to be socially, physically and economically accessible to the food which is simultaneously safe and is consumed "in sufficient quantity and quality in order to meet their dietary needs and food preferences and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life"(FAO, 2012).

Food security also becomes a concern on the urban level with cities incrementally reaching the statistic related to the number of food-insecure people in rural areas (FAO, 2013). The fact that food is often associated with the rural policy has resulted in the food issues receiving less attention on the urban agenda. This divisional approach has limited the study of food provisioning to the rural scale, omitting the fact that demand for food products is the highest in the city as a space, level and scale. In such an approach, the failure in production is assumed the only driver of the failure of urban food security, instead of covering other factors such as failure in distribution, accessibility and affordability (Sonnino, 2009).

Although previously food security was considered an agricultural issue, the latest studies point out that implementing "technical fixes" to food production as a single measure lacks the capability to enhance food security. In other words, multidisciplinary and many-sided measures are required that integrate the adaptation of food systems to environmental changes, by consideration of wider issues based on food security as well as considering the climate change outlooks in development projects (Ericksen, Ingram, Liverman, 2009). An ecosystem-aware approach leads the concept of food security beyond factors such as productivity, trade and micro-economic issues to embrace a comprehensive outlook of sustainable food systems (Mohamed-Katerere, Smith, 2013).

The resilience of the urban food system is affected by climate change in two various means. climate change always had and continues to have a significant influence on the food provision ability of agriculture on a global scale (Garnett 2008). Due to global warming, some parts of the globe will be considered more productive which is an advantage for these regions, since they will experience longer growing seasons and also sufficient rainfalls. However, a vast majority of the globe will not follow a similar pattern, which means they are expected to be prone to drastic environmental events such as droughts and floods. In these circumstances, food scarcity will be an inevitable issue. Sub-Saharian Africa, the Middle East and South Asia are the regions which not only are considered the most food-insecure Areas, but also they are facing the increasing population and urbanization. These factors are forecasted to act as grave inhibitors to their agricultural production diminishing the output. it is expected that the increment and intensity of extreme climate events will bring the gravest consequences for food production and its insecurity, particularly in the most food-insecure parts of the globe (Easterling et al. 2007). It is evident that this will bring severe impacts also for the food availability, accessibility, food system stability and the use of the food (FAO 2008).

It is prominent to mention that the zero hunger sustainable development goal set by the United Nations considers a provision and solutions to support the maintenance of ecosystems and also improve the systems of sustainable food production in this way directly addressing food security. It is of note that all other sustainable development goals set by the United Nations are also correlated with the challenge of food security on various scales.

Nature-based solutions are also playing a significant role to fulfill the comprehensive and holistic approach to food security and are capable of addressing this societal challenge through various means of integration. Protection of wild genetic resources and managing wild species and supporting some solutions for irrigation water are some points regarding the fauna and flora that can be addressed through NBS. Moreover, stabilizing the food accessibility in case of natural disasters, climate change and political crises and instability is achievable through nature-based solutions, by concentrating on the restoration, conservation and management of ecosystems to provide the feasibility of delivering different services (IUCN,2013b)

Urban agriculture can also appear as NBS to address the food security challenge in various Urban contexts having a considerable impact on the food provisioning and bringing benefits for the aspects such as mental health, recreation and place-making. Nature-based solutions, so as to be capable of delivering their maximum benefits to the security and production of food, require integrating urban agriculture in a way that embraces various functions instead of concentrating merely on food production (Barthel, Parker and Ernstson, 2015).

The scarcity of land as a resource is one of the main global restrictions on urban agriculture and the enlargement of urban food production scales (Badami and Ramankutty, 2015). Often the lands which are more suitable for agriculture are serving for enlargement of the cities or construction of new ones and the same applies to the infrastructural and industrial development. This type of approach results in the deforestation that takes place, in order to fill the vacant gap of the land to serve the agricultural production. Moreover there is a rising interest in various types of land use such as housing in rural areas of some countries (Van Dam et al. 2002). The lack of land availability is an issue also in low-income countries with a high rate of urbanization which intensifies food insecurity (Satterthwaite, McGranahan, Tacoli, 2010).

Climate change and agriculture are linked in two significantly distinct ways. There is no doubt that agriculture is prone to the negative impacts of climate change. However, it is apparent that the field is responsible for the outstanding amount of GHG emissions which accelerate the phenomenon of climate change. Deriving from this fact, it is feasible to deduce that agriculture has considerable potential for climate change mitigation by utilizing agricultural applications and methods with the aim of diminishing

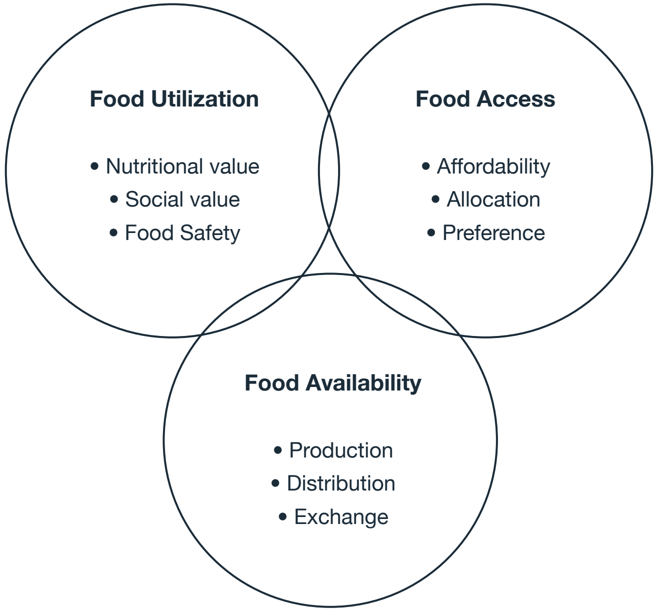


FIGURE 6:
The three components of Food Security (Beer T., Lin B., McGill A.)

the emissions caused by GHG (FAO 2008).
In this regard, Urban agriculture, due to its capacity of making and preserving open vegetated spaces and incrementing the greenery on the scale of the city is widely considered to have a substantial influence on the climate change adaptation and mitigation. reducing the urban heat islands and the flood risks are two brilliant points in the case. Moreover, some food provision phases such as the cool storage of certain types of products and food transportation can be diminished through the implementation of urban agriculture. As a consequence, there will be a reduction in GHG emissions by the field (Dubbeling, 2014).

3.3. Enhancing Biodiversity and Regulating Ecosystem Services

Following the rapid trend of urbanization in the world, there is a growing interest in understanding the benefits from local biodiversity in urban areas and the threats to these benefits due to climate change. “Urban biodiversity refers to the variety and variability among living organisms found in a city and the ecological systems in which they occur. Overall, urban biodiversity responds to a combination of biogeographic and anthropogenic factors, with an outstandingly stronger influence of the human related impact.” (De Oliveira, Doll, Moreno-Peñaranda, Balaban, 2014)

Researches have revealed that over the past decades more than 60% of the world's ecosystem services are degraded or unsustainably managed. Considering this fact and the biodiversity dependent nature of humans and life on the planet, biodiversity loss has become an urgent issue to address.

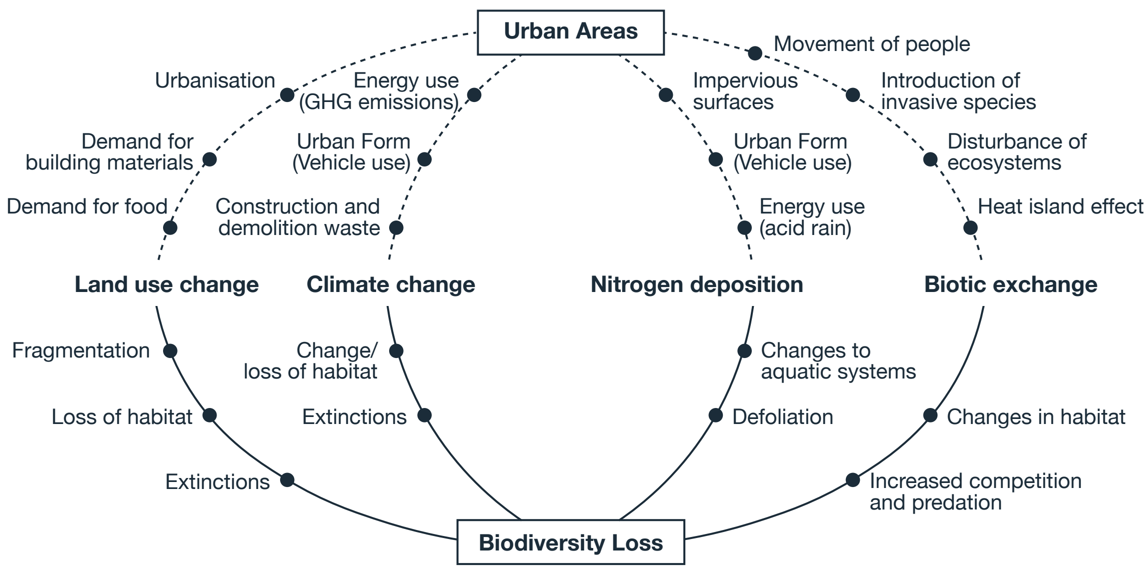


FIGURE 7:
Built environment drivers of biodiversity loss adapted from (Pedersen Zari 2014)

3.3.1.The Correlation of Biodiversity and Urban Lifestyle in Built Environment

The presence of biodiversity is the key support for human needs for survival as well as existence of life on the planet. Alterations in biodiversity are expected to affect ecosystem processes and functions, consequently ecosystem services might be altered. These are the directly or indirectly benefits that humans derive from the functions of ecosystems and can affect human life. (Potschin M, Haines-Young R., 2016)

Most of the cities are historically developed in important ecosystem junctions with rich biodiversity. Transformation of landscapes and human-caused changes have impacted the levels of biodiversity and are still causing alterations in local ecosystems. Apparently, alteration in the land use due to urbanization, climate change, deposition of nitrogen and biotic exchange (presence of invasive species) are the main factors leading to loss of biodiversity in urban areas. (Pedersen Zari 2018)

Similarly, the loss of biodiversity turns out to have a significant impact on human life quality in terms of climate change, reduction of resilience and ecosystem services, resulting in degradations in urban areas. This phenomena is most likely to endanger human physical and psychological health, societal,cultural and economic aspects and stability. Figure 2 illustrates some of these relationships. (Pedersen Zari 2018)

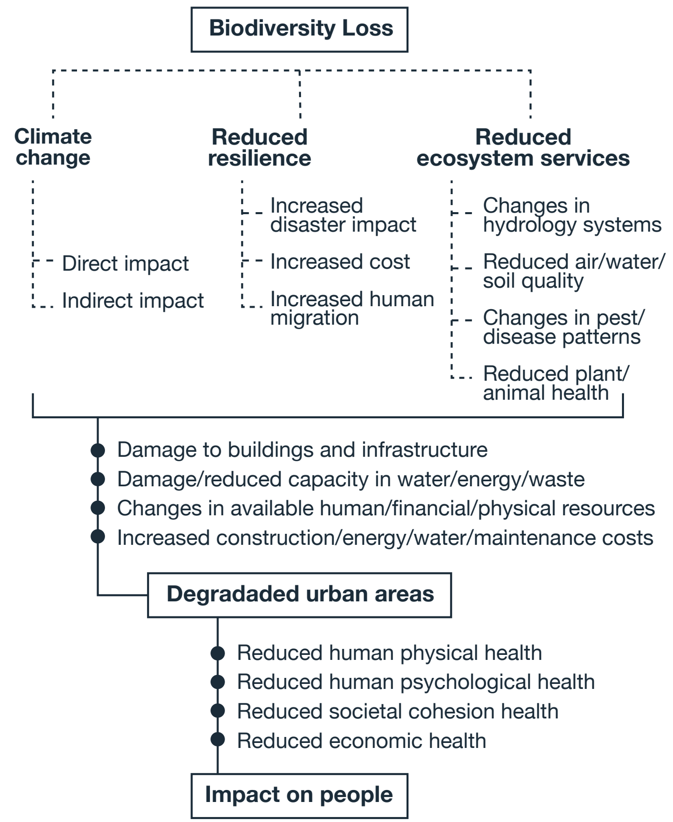


FIGURE 8:
Impacts of biodiversity loss on cities and people. (Pedersen Zari 2018)

3.3.2. Incorporation of NBS to Achieve Biodiversity in Cities

Having the climate adaptation and mitigation goals in agenda, NbS has a great potential to assist sustainable urban development. Restoring nature may lead biodiversity to thrive and human habitats to increasingly achieve long-term resilience. The contribution of NBS on enhancing biodiversity is complex and yet immeasurable by a single metric. However, there is enough evidence to insist that NBS have a positive impact on nature and biodiversity by various aspects.

Firstly, NBS can be effective in creating spaces and greater connectivity for wildlife in urban areas. Continuous reduction of natural spaces in cities results in separation of populations, risking a great number of species to be affected by diseases, invasive species, climate change and extinction. NBS increases the area of habitat and can connect existing green spaces by means of habitat corridors, resulting in preservation and enhancement of spices in cities. In this respect, large green spaces provide indispensable habitat for species, protecting the diversity against the urbanization impacts. Artificial habitats incorporating natural features, such as engineered devices, green roofs and green walls, support significantly higher levels of biodiversity providing different habitat functions for their bird and insect users in respect to constructed gray infrastructure. Transformation of brownfield sites could also contribute to supporting biodiversity by mimicking the natural habitats and helping to maintain populations, while street trees can act as corridors between larger green spaces and parks. (Filazzola, A., Shrestha, N. MacIvor, J.S. 2019)

Secondly, NBS helps maintain suitable temperatures for native species. It is crystal clear that different species' living habits vary according to particular climatic conditions, and any alteration of these conditions may endanger the survival ability of the specific species. The cooling effect of NBS has an essential role to combat the urban overheating issues and reduction of UHI effect. By creating cool hubs it can be influential on maintaining a consistent level of temperature for survival of biodiversity. Green walls, for instance, are capable of reducing the outdoor temperature between 0.5°C to 4°C, while street trees, urban green spaces and green roofs can reduce the surrounding air temperature approximately 3°C , 2.7°C and 0.8°C respectively. Furthermore, NBS can limit disruption to wildlife by reducing noise pollution.Along with various types of pollutants present in the atmosphere, noise resulting from human activities is classified as pollutant which negatively impacts wildlife. Noise pollution is most likely to disrupt species' living habits such as communication ability, migratory paths, hunting etc.

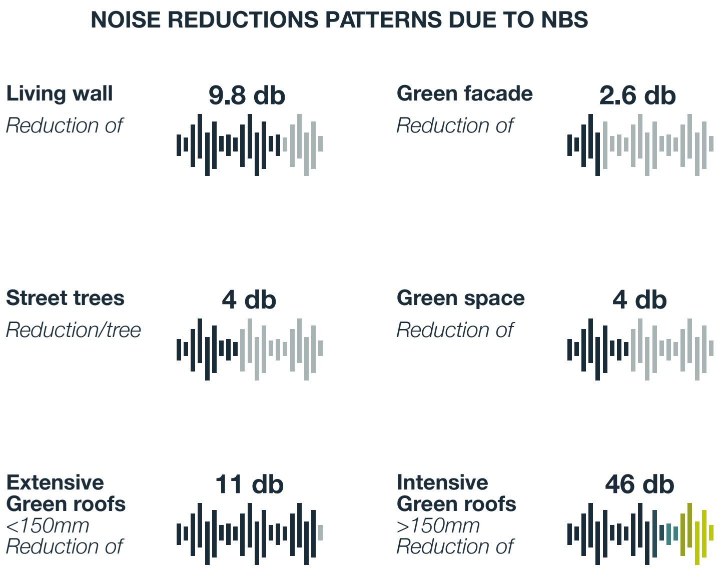


FIGURE 9:
Reduction of noise by various NBS

(Kunc H.P., Schmidt R., 2019).
The ability of NBS in reflecting and absorption of acoustic sound energy is particularly useful to reduce traffic noise and to limit noise pollution in urban environments, simultaneously reducing the negative impact on wildlife.
Finally, NBS supports the reduction of the run-off of pollutants into aquatic ecosystems and the consequent impacts. The gradual increase in the concentration of phosphorus, nitrogen, and other plant nutrients in aquatic ecosystems such as lakes and rivers lead to eutrophication. In certain conditions these chemicals can develop algae which can result in the depletion of oxygen from the water, and decrease in biodiversity, subsequently causing destruction of aquatic life dependent on oxygen. The predicted ability of NBS to filter the water pollutants and regulate algae development is a promising opportunity to deduce the expected 95% increase of eutrophication by 2050 (Clair N. Sawyer 1966).
Achieving biodiversity goals in urban areas will be possible through a specific focus on the conservation and restoration of species. Along with appropriate

placemaking and planning strategies, protection and integration of existing green space can be influential to introduce moderately built environments in order to support higher diversity of species. Meanwhile, the participation of local people and communities in biodiversity objectives is another requisite to maximize the achievements in providing biodiversity in the built environment. (Kowarik, Ingo, Fischer, Kendal, 2020)

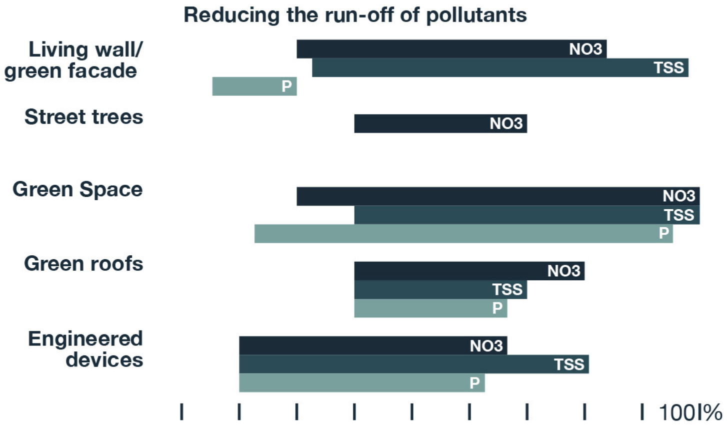


FIGURE 10:
Water quality improvement perspectives, reduction of the run-off pollutants: NO3 – Nitrates | TSS – Total Suspended in Solids | P – Phosphorus

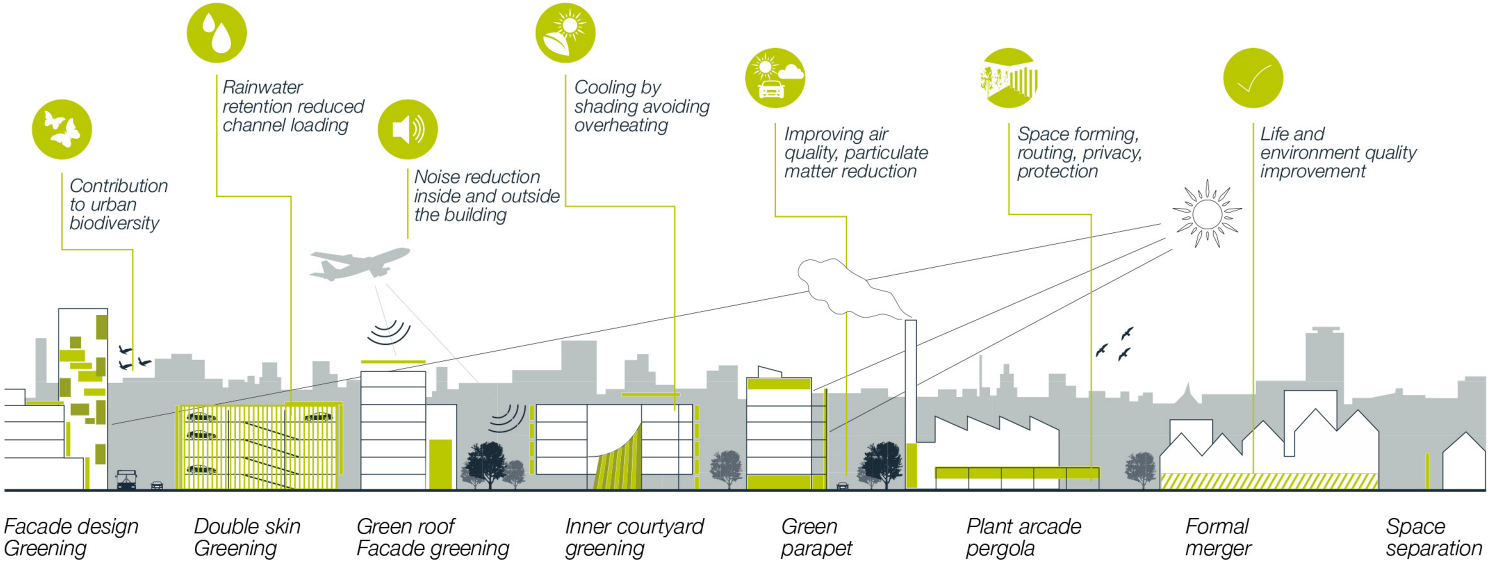


FIGURE 11:
Reasons to green buildings (Pfoser and Jakobs AG 2013)

3.4. Other aspects of NBS implementation developing sustainable communities

NBS have been found to stimulate several other factors addressing societal challenges and contributing to the sustainable development of communities. In addition to coping with above mentioned challenges, “Urban areas and enhancing sustainable urbanization” are one out of four principal opportunity fields for NBS suggested by the European Commission. That is due to the holistic approach of NBS aiming to tackle societal challenges, while enhancing the links between various beneficiaries.
NBS are responsible to provide conditions contributing to the improvement of life quality in the urban areas. The quality of life has been defined “as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns” and “is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment” (WHO, 2020).
Besides, socio economic values are also widely affected by the presence of NBS in the urban communities, being reflected on issues such as social cohesion, safety, land and property value, economic growth, etc.
This section considers how NBS contribute to distinct values, namely: The environmental health and human wellbeing, the social equity and resilience, and the improvement of local economy, leading to sustainable development of urban communities.

3.4.1 NBS for Environmental Health and Human Wellbeing

Increasing urbanization is one of the most significant drivers to health issues in our times. Limited access to nature and nature oriented outdoor activities may affect city dwellers in different ways. (Cox, Hudson, Shanahan, Fuller, Gaston, 2017)
The potential of positive impacts of NBS on population wellbeing in urban environments is respectively high. Besides providing habitat for animals such as songbirds, mammals and butterflies, and creating fascinating neighborhoods, NBS acts as inspiration for the residents to get involved in activities such as

walking, cycling or exercising, while being engaged more frequently with their local green space. Although dimensions of the direct impact of NBS on human health is yet to be discovered, the data related to the contribution of urban green spaces clarify that urban green can provide multiple health and wellbeing benefits:

Firstly, the presence of green spaces in urban areas is acknowledged to deduce the level of pollutants in the air by capturing and deposition. Research revealed that poor air quality has a considerable contribution to both minor symptoms such as headaches, eye irritations or colds, as well as more serious diseases such as heart disease, strokes, respiratory disease, cancer and death (WHO 2021). Therefore, NBS might have a significant role to play in this respect.

Secondly, there is sufficient evidence to declare urban green as significantly influential on improving human mental health. Although there is no specific quantification for this interaction, studies have found several facts regarding this matter. For instance, exposure to green facades enhances human physiological relaxation, (Elsadek, Liu, Lian, 2019) depression levels are expected to decrease by 7% with 30 minutes of weekly exposure to outdoor green spaces (Shanahan, Bush, Gaston, Lin, Dean, Barber, Fuller, 2016), while anxiety/mood disorder is likely to decrease by 4% with every additional 1% green space near home (Nutsford, Pearson, Kingham, 2013). Additionally, biodiversity and richness of species have a positive correlation with mental wellbeing. (Dallimer, Irvine, Skinner, Davies, Rouquette, Maltby, Warren , Armsworth, Gaston, 2012)

Finally, urban green has been proven to support human physical health through placemaking for leisure and recreation and encouraging physical activity. According to studies people living in greener areas or in the vicinity of green spaces are more likely to integrate exercising in their daily life schedule. This helps to attain the required amount of physical activity leading to a high level of general health and reduction in the rate of related diseases and mortality (Mytton, Townsend, Rutter, Foster, 2012).

3.4.2 NBS for Social Equity and Resilience

Despite the strong evidence for the efficacious contribution of NBS on citizens' wellbeing and quality of life, the manner of distribution and also the possible effects on intensification of existing social inequalities is a growing matter of debate in recent years.

Regarding this issue, there is enough proof that NBS is mostly implemented in neighborhoods with higher socio-economic status where the levels of wellbeing and life quality are already high (Anguelovski et al., 2019). The pattern has not undergone a significant change throughout the history of urban development and planning, introducing numerous illustrations of green spaces more often realized inside or in vicinity of upmarket housing environments, leading to socio-spatial inequalities within the urban environment. Therefore, the contemporary declining trend of experiencing nature is particularly evident in the most deprived communities, leading to environmental justice and equity issues.

Furthermore, there might be a sense of deprivation or exclusion of access to the green facilities suggested by NBS in the format of realization of green gentrification in neighborhoods, as the local community might have limited access to the facilities designated for the private use of new residents or businesses. Meanwhile, the growing price of properties with open access to the new facilities may lead the locals priced out of the housing market (Hawxwell et al., 2018).

Despite the above mentioned points, evidence demonstrates that NBS in the built environment aim to address urban inequality challenges. For instance the studies of Green Locally Unwanted Land Uses (GREENLULUS) project on forty cities in Europe reveals that almost 50% of cities "employed greening as a way to improve living conditions and address disinvestment in socially vulnerable neighborhoods" (Connolly et al., 2018). This can not be achieved unless by adopting socially inclusive urban development strategies, which is defined as "a development considering the needs and wants of all groups of urban inhabitants as well as the different capabilities, capacities and constraints of people to benefit from goods and not to suffer from burdens." (Haase, 2017) Excluding the socio-economic and socio-cultural challenges of local communities is feasible through implementation of participatory placemaking approach, in which co-design, co-creation and co-management of NbS incorporate the benefits of various stakeholders. This collaborative process, despite confronting some limits concerning time, skills and financial resources, is likely to generate novel methods of governance and distribution of potential values and benefits contributing to the sustainable development of communities in urban areas.

Additionally, NBS have a significant role in providing social awareness about nature in the built environment, where the interconnections between human and nature might be limited by far. Introducing nature in cities provides an evident understanding about the beneficial influence of nature on societies, as well as the importance of further actions to protect nature. Therefore, increasing awareness on this matter may grow wider in scale and result in a global reduction of environmental impact creating a more holistic perspective for sustainable communities.

3.4.3 NBS to Improve the Economy

There is now extensive evidence that several variations of economic benefits in urban areas can be directly affected by the presence of NBS. These include not only the individual benefits of the city dwellers, but also the ones associated with the local economy, urban infrastructure and the environment, taking its role to enhance economic sustainability.

There is no doubt that NBS are able to support human mental and physical health and wellbeing. Decreasing health issues in society not only reduce the costs related to personal health issues, but they also contribute to human resource availability in workplaces, resulting in increased productivity. Apparently, an outstanding percentage of city inhabitants are diagnosed with a severe health condition in some stage of their life, causing restrictions on getting back to their jobs. In this respect studies have revealed a 6-7% increased productivity and 23% decrease in sick leave taken by employees with a view of nature (Heschong, Mahone, 2003).

Furthermore, implementation of NBS in a densely built environment and suggesting high-quality accessible green spaces and rooftops may improve the aspects of the local businesses, consequently affecting the customers behavior and willingness to spend on services and products. Research demonstrates that customer spendings and restaurant patronage may increase upto 50% due to street trees, while 50% of park visitors appear to visit a local business in the area (Wolf, 2003).

On the other hand NBS in the built environment turns out to be an influencing factor on the attractiveness and value of property in distinct manners. Firstly, they capture the fascination of the people regarding the suggested view and recreational facilities. Therefore, they are increasingly more intended to buy or rent properties benefiting from NBS. Secondly, NBS can extend the lifespan and durability of the buildings, by limiting the exterior surfaces direct exposure to the environment and protecting them from overheating, temperature fluctuations, acid rain, etc.

Moreover, cities are forced to bear enormous expenses for the maintenance of the traditional gray infrastructure being affected by the climate change impact. NBS are able to reduce the soaring costs related to the management, maintenance and adaptation of existing infrastructure to climate change. Meanwhile, along with the substantial preservation and restoration of environmental quality, accessible and multifunctional NbS act as an encouraging factor for local investment, stimulating the sustainable development of the local economy and revitalization of communities (Liekens,De Nocker, Broekx, Aertsens,Markandya, 2013).

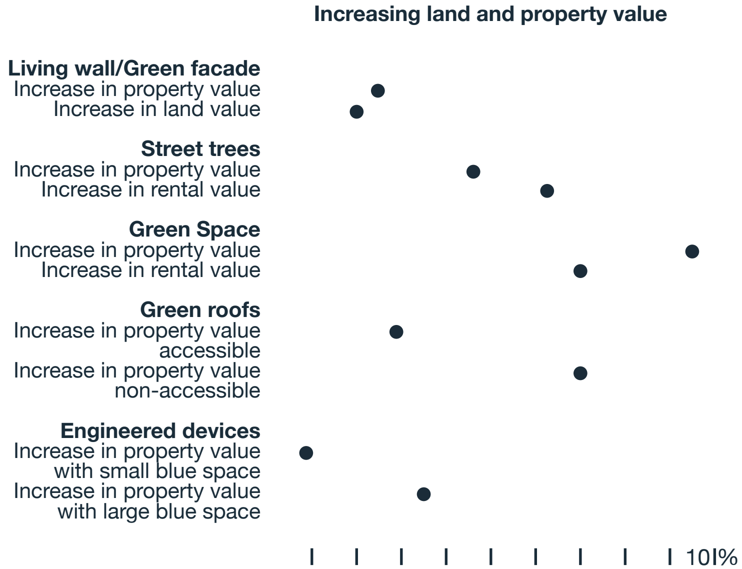
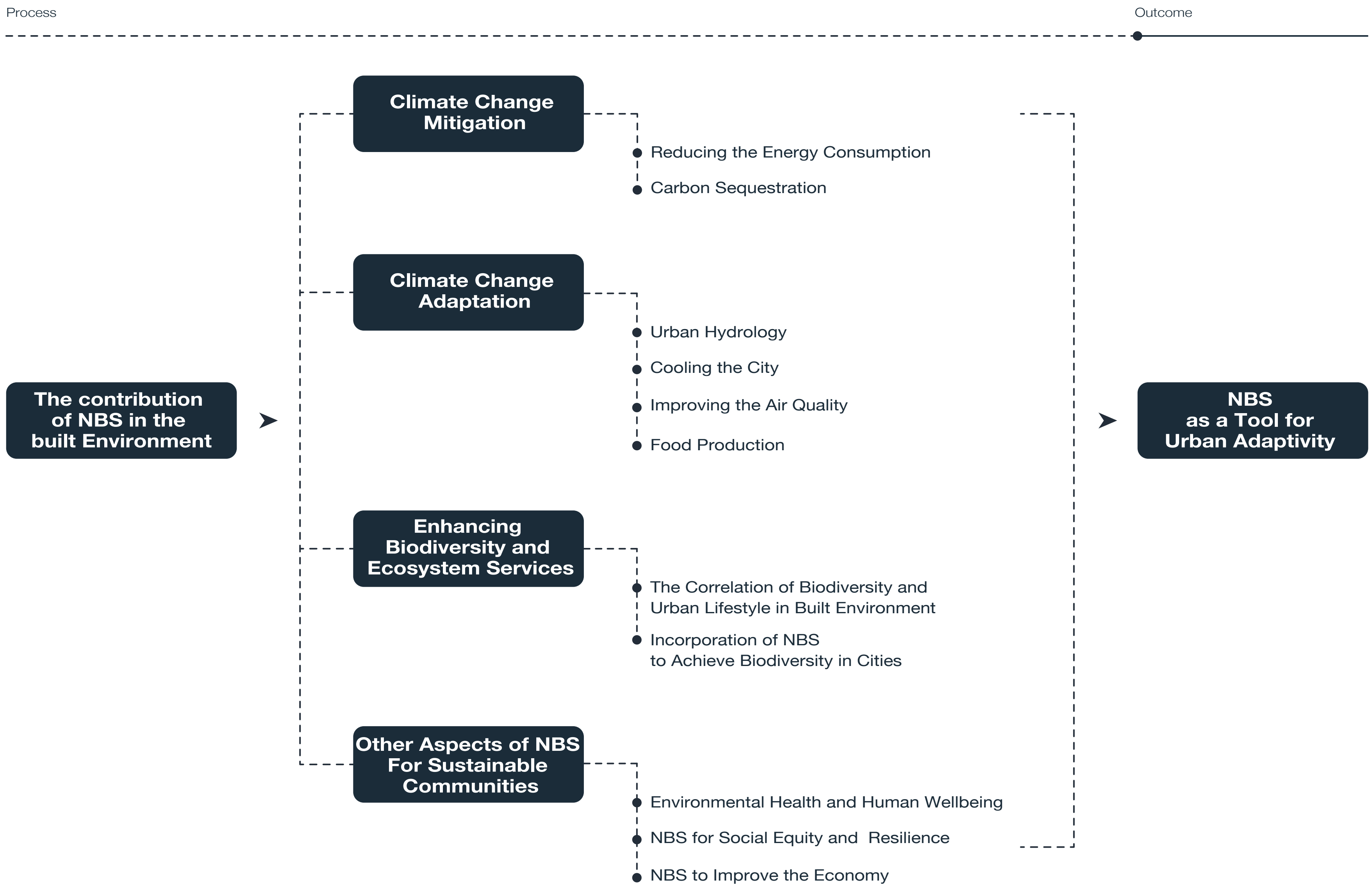


FIGURE 12:
Land, property and rental value increase perspectives


Process
Outcome
The contribution of NBS in the built Environment
Climate Change Mitigation
Reducing the Energy Consumption
Carbon Sequestration
Climate Change Adaptation
Urban Hydrology
Cooling the City
Improving the Air Quality
Food Production
Enhancing Biodiversity and Ecosystem Services
The Correlation of Biodiversity and Urban Lifestyle in Built Environment
Incorporation of NBS to Achieve Biodiversity in Cities
Other Aspects of NBS For Sustainable Communities
Environmental Health and Human Wellbeing
NBS for Social Equity and Resilience
NBS to Improve the Economy
NBS as a Tool for Urban Adaptivity

CHAPTER 4
MITIGATION AND ADAPTATION TOOLS AND STRATEGIES

4. Mitigation and adaptation tools and strategies

Dealing with contaminated sites is a widespread global issue in contemporary urban areas, especially those with an industrial background. The post industrial context has left modern cities with the scars of the past: the ample abandoned spaces and sometimes contamination due to former industrial activities. However, these spaces are not only an important part of the public memory, but also a huge potential for the regeneration of the cities to tackle the new climate change era. Therefore, strategic development of remediation processes combined with the functional revitalization of these spaces can help reduce their risk for human health and the environment and optimize use of brownfields as resources.

This chapter introduces some of the relevant tools and strategies which can be applied in different stages of the projects with an intention of mitigating extreme conditions and adapting to the climate change, being the analytical phase, site inspection, conceptual development, design and post design phases, suggesting the opportunity to measure and compare between the distinct phases in order to find the most effective solutions.

Having a profound pre investigation in the implementation of NBS this research suggests to consider them as a tool for mitigation and remediation of contaminated urban areas, discussing nature-based strategies with a more profound interpretation of:

- Phytoremediation and phytomanagement
- Constructed urban wetlands

The effectiveness of the NBS is measurable due to some evaluation and assessment tools and approaches which are represented in this chapter:

- Ladybug Tools
- i-Tree tools
- Envi_Met
- LIM approach

Furthermore, the research has discussed "adaptive reuse" as a tool for reaching urban resilience, consequently, a mitigation and adaptation approach in its own frameworks.

4.1. Nature-Based Strategies

The various scales of NBS application

The geographical situation is a key indicator in choosing the most suitable NBS defined on various urban scales. The research is focused on the NBS benefits on the city and neighbourhood scales (Figure 1).

Figure 2 illustrates a selection of the suitable strategies taking into the account the city and neighborhood specific challenges describing the feasible implementation approaches and contribution to be delivered by each of the considered strategies.

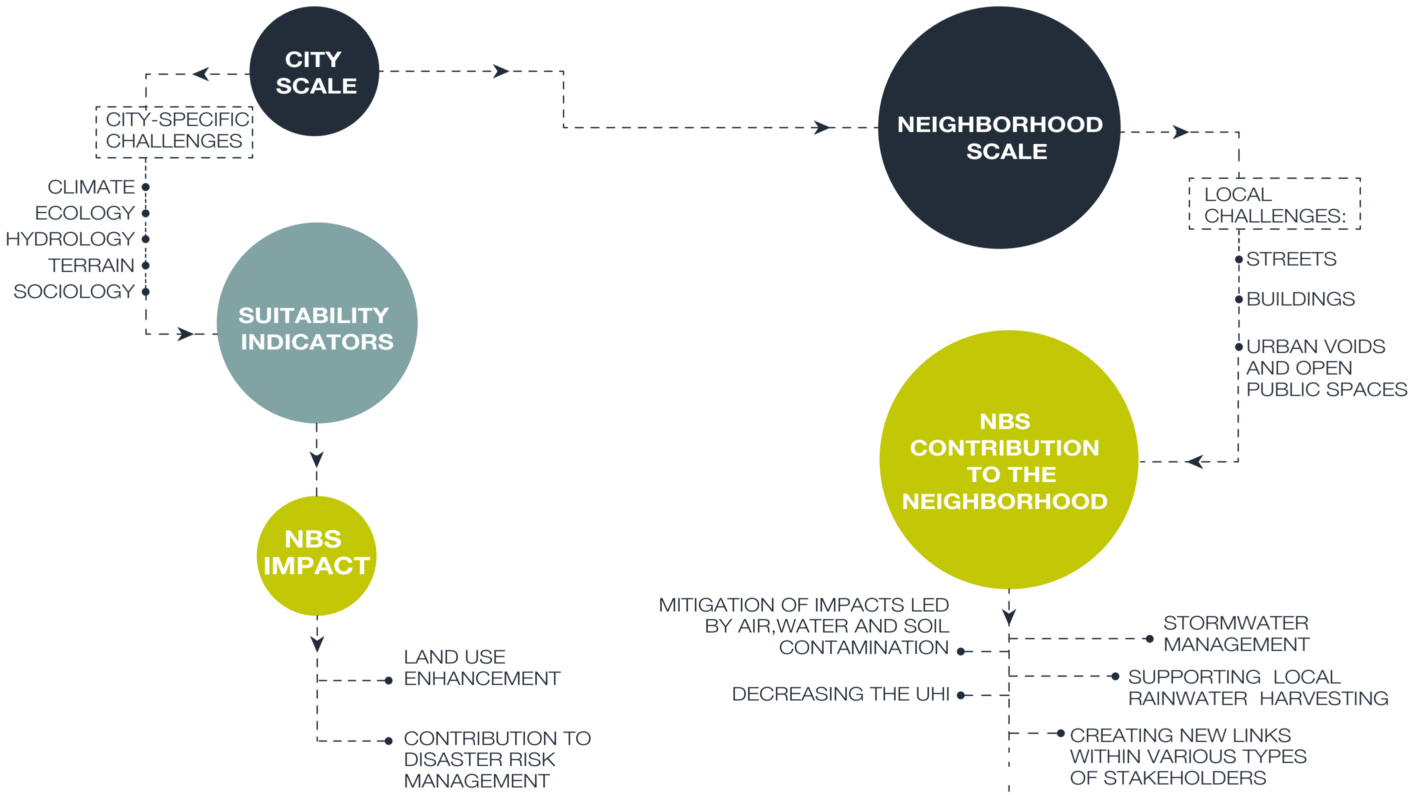
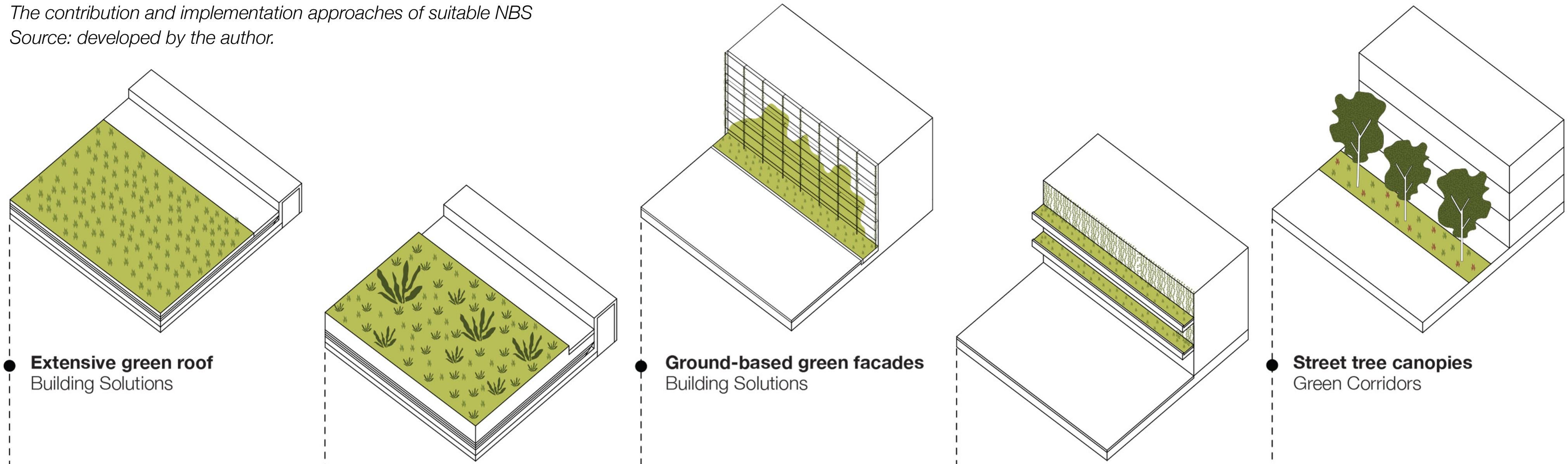


FIGURE 1:
NBS on the city and neighborhood scales
Source: developed by the author.

FIGURE 2:
The contribution and implementation approaches of suitable NBS
Source: developed by the author.



Extensive green roof
Building Solutions

Approach: Designs of building with green roof or apply on existing ones.

- Water management and filteration
- Insulation and cooling
- Feasibility to include social interactions, and recreation

Intensive green roof
Building Solutions

Approach: Design of buildings with green roof or apply on existing ones.

- Ability to carry a wide range of species Water management and filteration
- Insulation and cooling
- Attracting the biodiversity
- Feasibility to include social interactions, and recreation
- Urban Farming
- Possible integration of educational activities in form of a classroom or Even specilized LABs

Ground-based green facades
Building Solutions

Approach: Design of buildings with green facade or apply on existing ones.

- Shading provision for the facade
- Mitigation of Air pollution which enhances the occupants' health
- Aesthetic support to the architectural design
- A suitable solution for integrating climbing and self-clinging species which can grow directly on the building envelope or on a designated structure with joints to the facade

Facade-bounded greening
Building Solutions

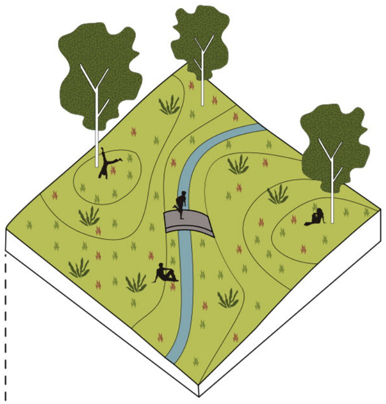
Approach: Design of buildings with green facade or apply on existing ones.

- Shading provision for the facade
- Mitigation of Air pollution which enhances the occupants' health
- Aesthetic support to the architectural design
- A suitable solution to provide a diverse mix of plants in the vertical direction
- Decreasing the overall load of the green wall due to the implemented substrates on the facade

Street tree canopies
Green Corridors

Approach: Conserving the exisiting drainage network and trees. Combine the components of existing green infrastructures, develop them as a linked network, extending in city.

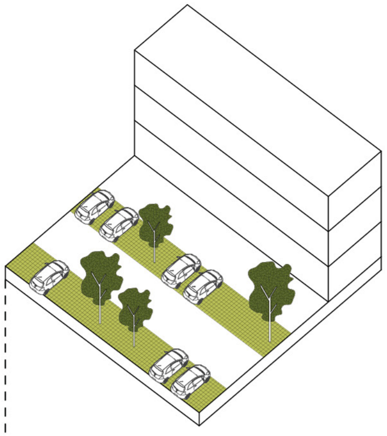
- Shading provision for the streets which reduces the tempreture of air and surrounding surface
- Cool paths absorb people creating opportunities for social interactions, shops and services
- Certain tree species are attractive for visitors



Natural playgrounds
Open Green Spaces

Approach: Protect and renovate the actual green space. Temporary utilization of undefined areas as open green space along with designing new ones.

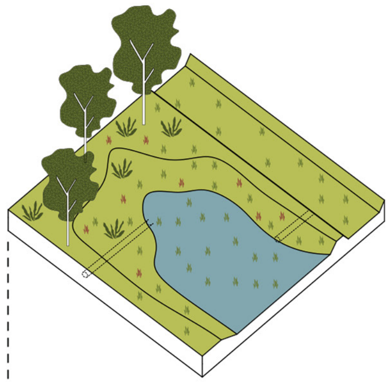
- A key supporter of social interactions and sports activities
- Presence of natural elements such as plants, flowers, rocks and water surfaces, enhance creativity and the ability to appreciate and perceive nature among children
- A potential venue to conduct educational and cultural activities as well as the recreation
- Coping strategy for the stormwater challenges



Permeable pavements
Bioretention Areas

Approach: Improve entire drainage system on the street border edges and designate green strips all along the street.

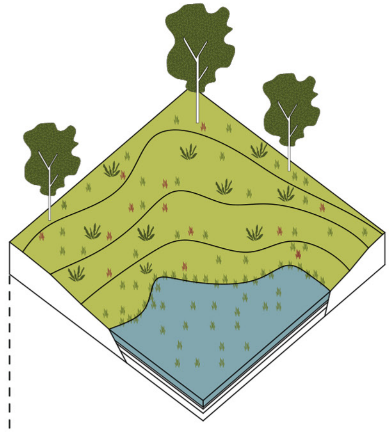
- Their water storage capacity treats and copes with runoff the rainwater, by absorbing transefring the water to their reservoir layer underneeth
- Integratable both on the urban and building scales



Retention pond
Bioretention Areas

Approach: Improve the entire drainage system. Create new bioretention areas.

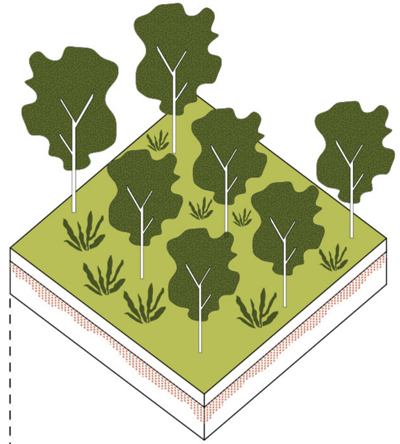
- Deep areas to temporarily hold the stormwater during rainy seasons having the capacity to be totally filled by water
- The water level doesn't exceed the pond's capacity limits since it is discharged to the sewer system
- Ponds could be combined with other applicable functions such as playgrounds because the level of the water decreases when they are no heavy rains



Surface constructed wetlands
Constructed Wetlands

Approach: Transforming the actual green spaces to wetlands in case it's a solution to a site-specific challenge or construct a new one.

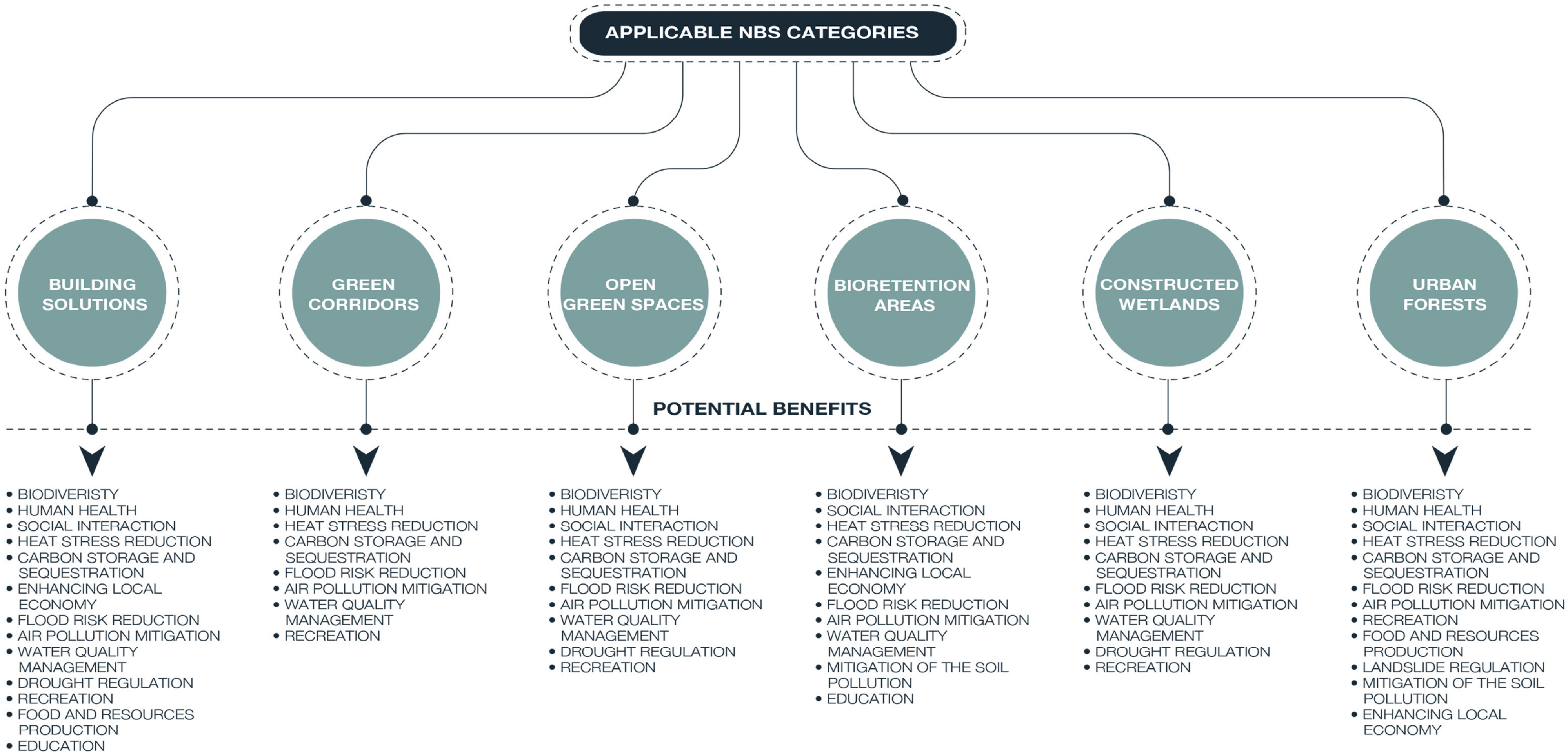
- Attracting the biodiversity
- Filtering water by cleaning it from contaminants through vegetation planted on the Incrementally decreasing slope into the soil
- Properly designed wetlands are efficient for Carbon storage and sequestration



Phytoremediation forest
Urban Forests

Approach: Plant in contaminated areas to remediate the contaminants and restore usable spaces.

- Combination of the plants with specific feature of absorbing contaminant from the soil is a key strategy especially for the abandoned industrial areas with the presence of heavy metals in the soil
- A well-organized phyto-management would be fruitful with economic revenues



Applicable NBS categories

The feature of NBS to be applied on various scales, creates the necessity to distinguishing them into the distinct categories (World Bank, 2021). The strategies discussed in figure 2 belong to different categories introduced in figure 3 which describes the applicable categories corresponding to the site-specific challenges. Moreover, it also sheds light on the potential individual benefits to be recieved from the categories.

FIGURE 3:
Applicable NBS categories and their potential benefits
Source: developed by the author.

4.2. NBS as a mitigation and remediation tool for contaminated areas

The practice of cleaning the contaminated areas specially in the urban context often surrounded with other properties is a debatable discussion, often finding very individual solutions for distinct cases.

Generally, the so called pollutants can appear in the environment as a result of a large variety of processes, including the natural ones. For instance, heavy metals naturally appear in the environment due to erosion of rocks, decay of plants and animal waste, precipitation, particles from volcanic eruption and forest fire. But the awkward concentration of toxic heavy metals in the built environment which is a more concerning issue is mainly due to human activities, such as domestic waste, vehicle emission, industrial processes, occurring in water, soil and air. Apparently, these pollutants are assuring a long term presence in different layers of aquatic and soil ecosystems unless measures are taken for their removal.

The presence of toxic pollutants in the environment is considered risky for the complex system of reaching resilience, with a negative impact on several target categories of sustainable development (figure 5). Therefore, remediation of a contaminated area is mostly a requirement before developing a new project, especially when dealing with brownfields. Brownfields remediation experience has revealed several methods during the time. The most common ones are represented in figure 6 (Vaishali A., Babita K., July 2021).

This research has focused on the methods based on the NBS, in order to discuss a different dimension of NBS as a tool for remediation of contaminants.

FIGURE 4:
Chernobyl sunflowers project, NBS for nucle-ar remediation.
Source: https://medium.com/, 2020

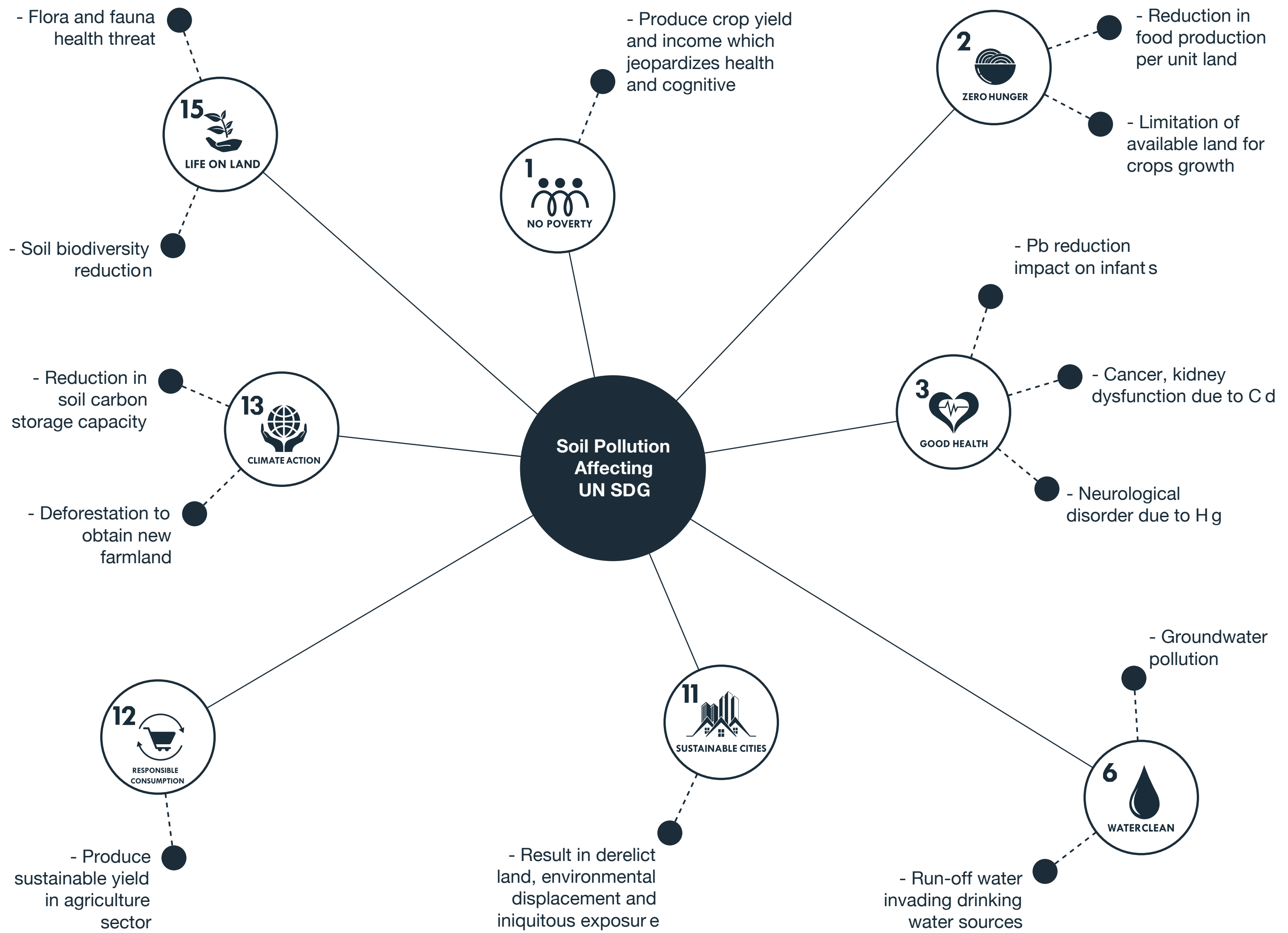


FIGURE 5:
The negative impacts of soil pollution on SDGs.
Source: (Vaishali A., Babita K., July 2021)

AVAILABLE REMEDIATION TECHNIQUES FOR HEAVY METAL CONTAMINATED SOIL				
Methodology	**Technique**	**Applicability**	**Advantages**	**Limitations**
Physical Remediation	Surface Capping	In Situ, in areas with excessive heavy metal pollution	Applicability is unchallenging, low operating cost, high security	Limited to small land areas, and applicable at specific geographic locations, deprivation of land
	Landfilling	Ex Situ, applicable to areas with high metal pollution	Immediate restoration, high security	High capital cost, supplementary land is required for storing of the unproductive sediment
	Encapsulation	In Situ, applicable to areas with high heavy metal pollution	Effective isolation of heavy metal from sediment, quick installation	Limited to small scale and shallow land areas, costly,
	Soil Washing	Ex Situ, applicable to soil with moderate to high pollution	High efficiency, quick remediation, absolute removal of heavy metals	Effectiveness varies with physicochemical nature of soil, drastic soil disturbance might accure
	Excavation of Soil	Ex Situ, applicable to areas with high heavy metal contamination	Effective removal of heavy metal, quick completion of process	Production of harmful waste products which can have negative impact on soil, costly
Chemical Remediation	Stabilization	In Situ, applicable to areas with high heavy metal contamination	Affordable, easy, effective, covers a broad-spectrum of pollutants	Specific to different metals, temporary, constant monitoring required, remnants will be present soil
	Solidification	In Situ/Ex Situ, applicable to high heavy metal contamination	Quick implementation, high efficacy	High capital cost, treated land loses important ecological functions
	Vitrification	In Situ/Ex Situ, applicable to high heavy metal contamination	High efficiency, easy to install, applicable to various contaminants	High capital (energy requirement), limited to small areas, treated land loses its environmental value
	Electrokinetics	Ex Situ, fine soil, applicable to moderate/high pollution	Easy application, economically effective,minimum soil deterioration	Time-consuming, low efficiency, for fine-textured soil with low permeability, pH control required
Bioremediation	Phytoremediation	In Situ, applicable to low to moderate heavy metal pollution	More public acceptance, economically effective, easy to apply	Limited to shallow land & specific metals, time-consuming, effectiveness depends on the growth conditions, and bioavailability of heavy metals
	Microbial remediation	In Situ, applicable to low to moderate-heavy metal pollution	Easy to implement,economical,low soil disturbance, less time required	Depends on microbes, soil, metal type, & plant, low efficacy

FIGURE 6:
Mechanisms, advantages and disadvantages of the available remediation techniques for heavy metal contaminated soil
Source: (Vaishali A., Babita K., July 2021)

4.2.1. Phytoremediation and phytomanagement

Among the existing remediation techniques, phytoremediation is the one which uses plants to extract, immobilize and volatize toxic metals from soil, sludge, wastewater, sediments, and groundwater. The process involves the absorption of contaminants by roots, and their storage in leaves of plants (Chibuike,G., Obiora,S., 2014). Along with the environmental benefit by removing the toxic metals, preserving biodiversity and improving air quality, nature based remediation promotes social benefits by improving aesthetics and health benefits, simultaneously ensuring economic viability due to a relatively low cost, use of renewable energy and the ability to control nonpoint pollution (figure 7).

The effectiveness and duration of the process is highly dependent on the species of selected plants. Hyperaccumulators and metallophytes are among the categories which can tolerate 100 to 1000 times higher levels of heavy metals and other contaminants than other plants (Burges et al., 2018). The process may be implemented by various native, imported, or genetically modified plant species, however, selection of local or locally adaptable species are

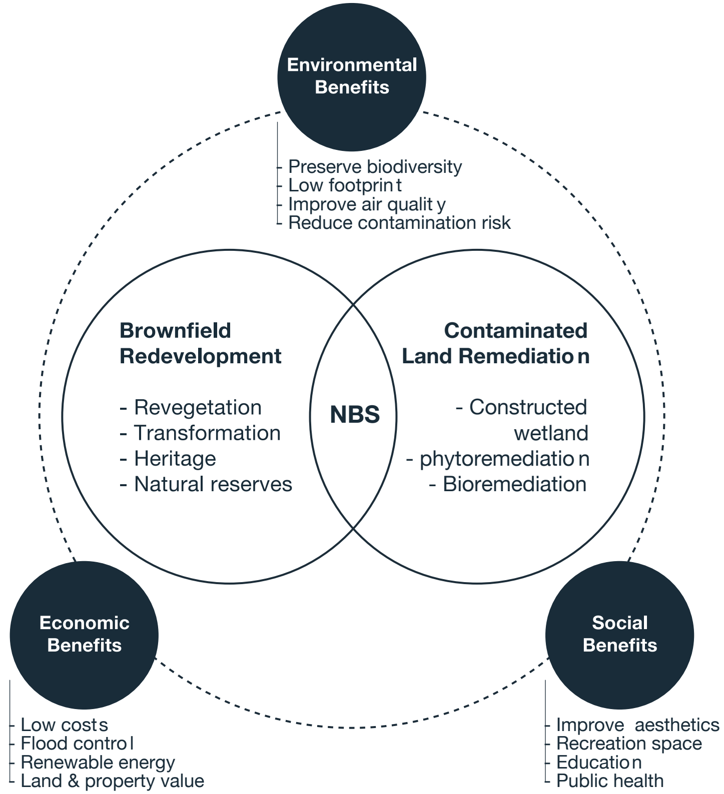
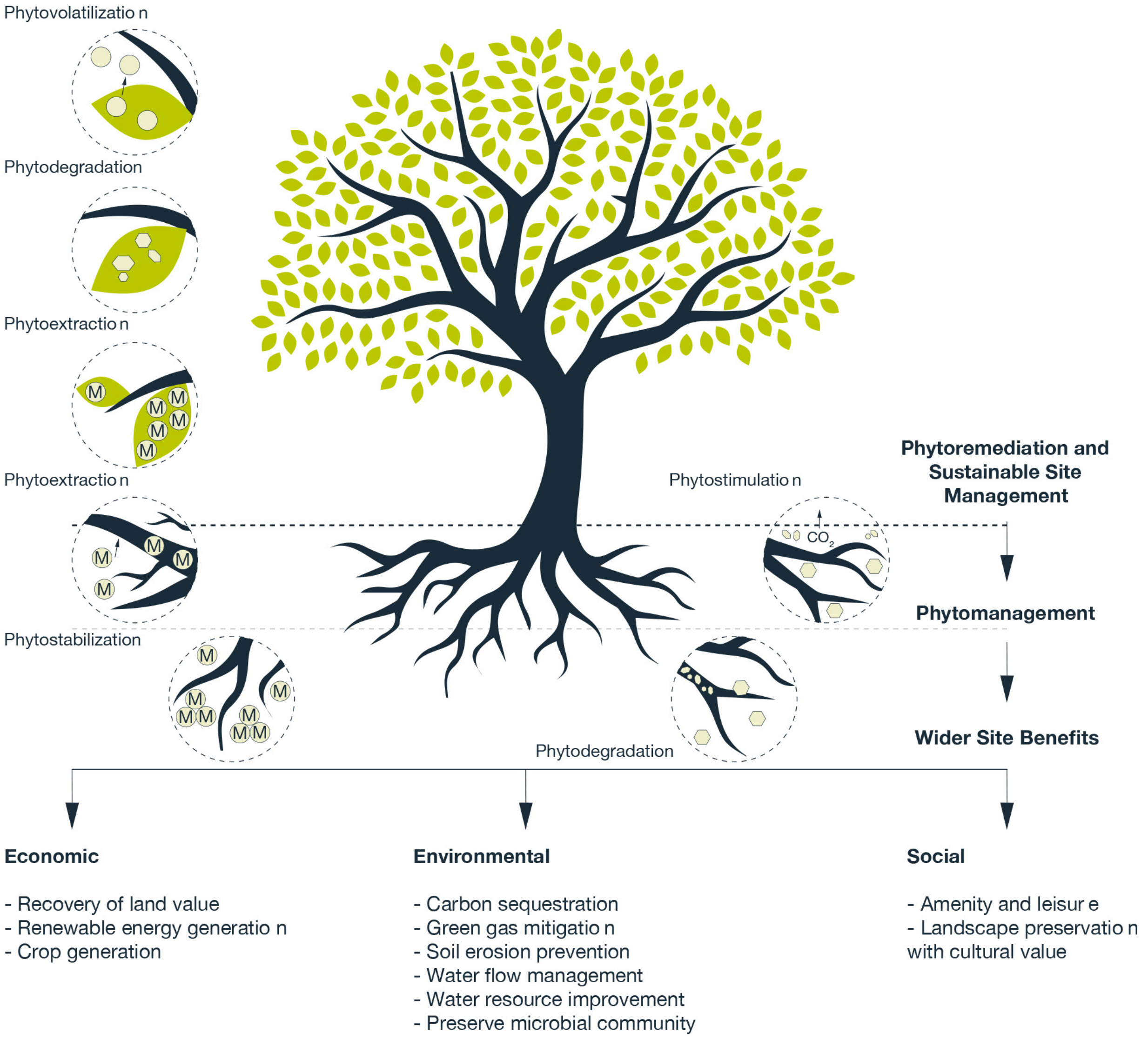


FIGURE 7:
Various aspects of NBS for brownfields remediation.
Source:(Song,Y.,Kirkwood,N.,Maksimović,C.,Zheng,X.,O'Connor,D.,Jin,J.,Hou,D., 2019)

FIGURE 8:
Phytoremediation Process
Source:(Awa,S.,Hadibarata,T., 2020)



often more convenient considering the ease of growth and maintenance.

The main strategies of phytoremediation technique:

Phytoextraction: a biochemical process which is responsible for the translocation of the contaminants from the roots to harvestable parts of the plant.

Phytofiltration: a contamination cleaning method with the use of plant roots (figure 8).

Phytostabilization: a strategy to stabilize the contaminants in the rhizosphere of plant species aiming to reduce the mobility and bioavailability of heavy metals. Modifying the pH and organic matter content in the sediment may enhance the efficiency of this technique.

Phytovolatilization: the absorption of contaminants through the plant roots, conversion to a gaseous state, and release into the atmosphere. This condition may occur if the metal accumulated is highly volatile.

Phytodegradation: a technique to transform the organic matter to non-hazardous chemicals. Utilization of plant-secreted enzymes is required in this strategy, while it is more efficient if combined with microorganisms (Awa,S.,Hadibarata,T., 2020).

Phytostimulation or rhizodegradation: the enhancement of soil microbial activity for the degradation of organic contaminants, occurring within the rhizosphere around the roots. The carbohydrates and acids released by plants stimulate microorganism activity, leading to the biodegradation of the organic contaminants.

The exorbitant cost of traditional methods often happens to be the reason to postpone or renounce the brownfields development projects. Despite their short duration, these methods are generally not compatible with the simultaneous use of the space by the public, therefore, the investors can only expect income when the cleaning and project realization process is completed. While many of these methods may result in loss of ecological functions of the soil.

Phytoremediation is respectively cost effective compared with other methods, it can be directly applied to polluted soil or static water environment, preserving the fertility of the topsoil. It improves the soil quality and plant phytochemicals. The plants have the capability to control the erosion and metal leaching in the soil as well as the potential of phytomining which is the recovering and re-use of valuable metals by growing high-biomass plants that accumulate high metal concentrations. Phytoremediation is easily applicable and adaptable with public activities, so the remediation and reuse can take place simultaneously, encouraging the stakeholders.

Phytoremediation is a time consuming process with its own risks as limitations regarding the reaction of the plants to the existing contaminants. The process might take years, while the depth of cleaning level is similar to that of the plant roots, providing a superficial cleaning possibility.

Consequently, effective results can be acquired due to proper management of the process. In this regard, phytomanagement is a novel concept focusing on sustainable risk-based land use with remediation as a secondary aim, seeking to achieve environmental, social and economic gains simultaneously. Providing much wider site benefits, it includes the generation of renewable energy by growing profitable crops, greenhouse gas mitigation, water flow management and landscape reservation (Burges et al., 2018).

4.2.2. Constructed urban wetlands

Constructed wetlands are artificial wetland systems using the natural functions of plants, soil, and organisms aiming to treat runoff water greywater and sewage due to enhanced sedimentation, fine filtration and biological uptake processes. These engineered systems slowly release the risen level of water during the rainfalls through the outlets, reaching the dry weather water levels within some days. Therefore, wetlands have a significant contribution to flood risk reduction by slowing and storing the surface water flows. Besides, wetlands provide habitat for a broad range of wildlife including insects and birds in urban areas, meanwhile creating a picturesque landscape and desirable places for people and local community, improving amenity, public health and wellbeing.

The cleaning process in wetlands takes place through four key mechanisms:

1. Nutruent uptake, is the accumulation of nutrients such as nitrogen and phosphorus by plants to grow.
2. UV irradiation exposure, which is helpfull for the removal of pathogens and breakdown of organic pollutants.
3. Sedimentation, due to the increased hydraulic resistance and reduce velocity caused by the plants, ensuring the drop out of suspended solids accompained with attached pollutants such as metals and nonsoluble phosphorus.
4. Microbial action, is the breakdown of organic pollutants, due to the large oxygen rich surface area created by the plants root for microbial biofilms.

the cleaning process (Russell, I., Pecorelli, J., Glover, A.,2021) (figure 10).

FIGURE 9:
Minghu Wetland Park by Turenscape Architects in Liupanshui, China
Source: https://www.archdaily.com/

Constructed wetlands generally consist of the following zones:

a. Inlet zone, which is the sedimentation basin removing coarse sediments.

b. Deep pools

c. Deep marsh macrophyte zone, a densely vegetated area for the removal of fine particulates and uptake of soluble pollutants.

d. High flow bypass channel, protecting the macrophyte zone from scour and vegetation damage (figure 11).

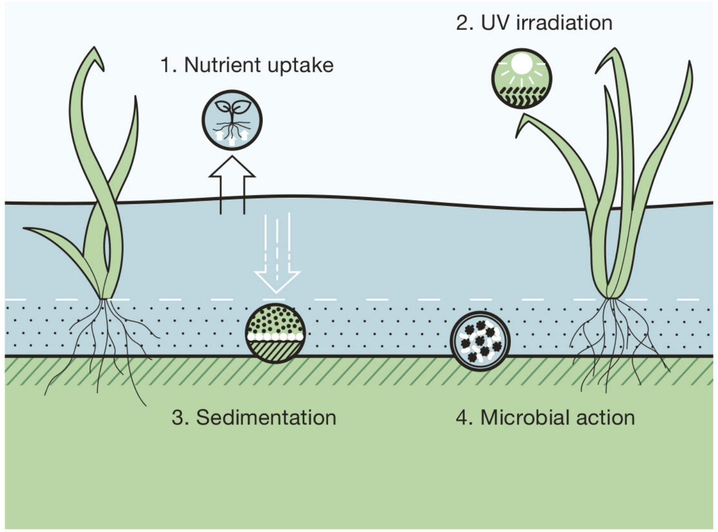


FIGURE 10:
Cleaning process mechanisms in wetlands.
Source:Russell,I.,Pecorelli,J.,Glover, A.,2021

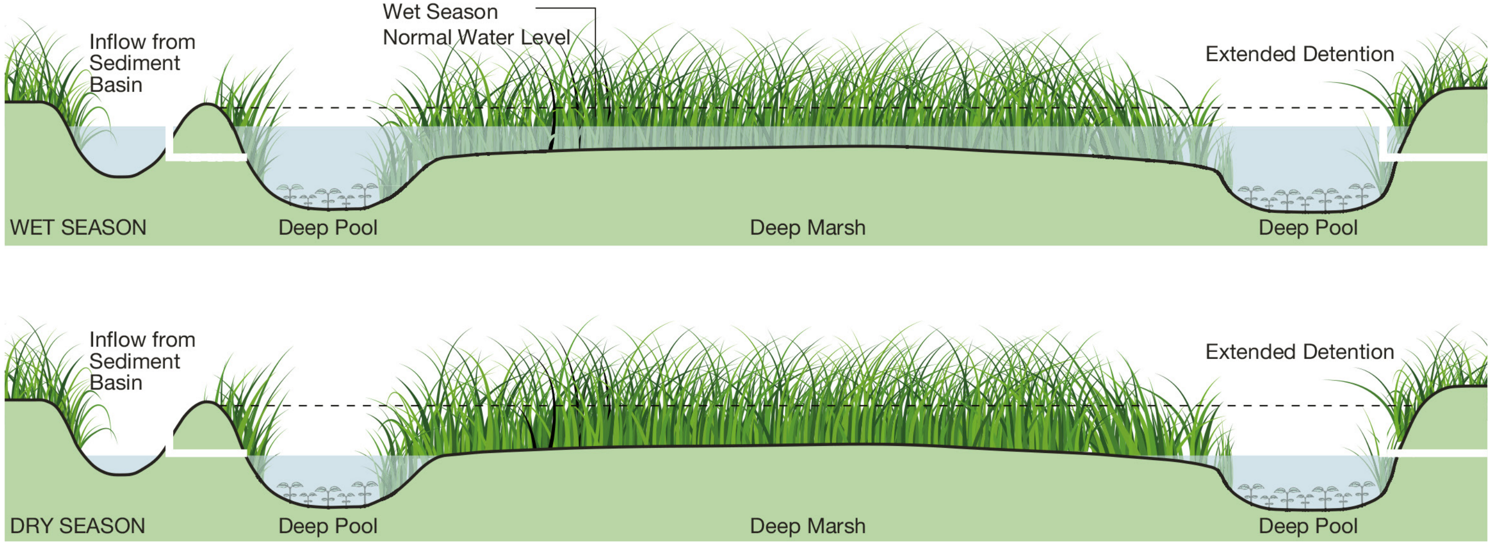


FIGURE 11:
Wet and dry season conditions in a Constructed Freshwater Wetland.
Source: Constructed Stormwater Wetlands, WSUD Technical Design Guidelines for the Coastal Dry Tropics

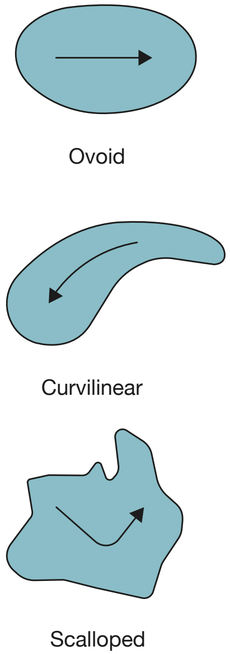


FIGURE 12:
Different types of wetland cell shapes
Source:Russell,I.,Pecorelli,J.,Glover, A.,2021

This study has investigated the following principals for urban wetland design.

1. Position and dimensions:

Depending on local topography the wetland must be allocated close enough to the surface water drainage network to ensure water collection into the wetland. It is recommended to place it in the vicinity of the pollution sources such as heavily trafficked roads to enhance the treatment benefit.

Dimensions of the wetland depends on the amount of inlet water and the surface of the catchment area. A good wetland system should be 1-5% of the catchment area (Kadlec, RH, Knight, RL,1996). The water depth can vary between 10-30cm in the shallow parts, and 200-300 cm in deep pools.

2. The shape and quantity of the cells:

Generally, the ideal shape for treatment purposes is the ovoid (length to width ratio 4:1). Curvilinear shapes and complex shapes with scalloped edges are also recommended as they increase the perimeter length of the wetlands, creating a richer habitat.

Due to their reduced effectiveness narrow longitudinal shapes are not recommended as these might result in increased flow velocity. The quantity of wetland cells is highly dependent on topography and characteristics of the site. However, 3-4 cells is the ideal minimum for a constructed wetland design. Multi-cellular design increases the treatment potential and the system resilience.

3. Wetland flows and Hydrologic Effectiveness

The inflows of wetland occur through the sedimentation basin which is responsible for the removal of coarse to medium sized sediment, controlling the flows before the macrophyte zone.

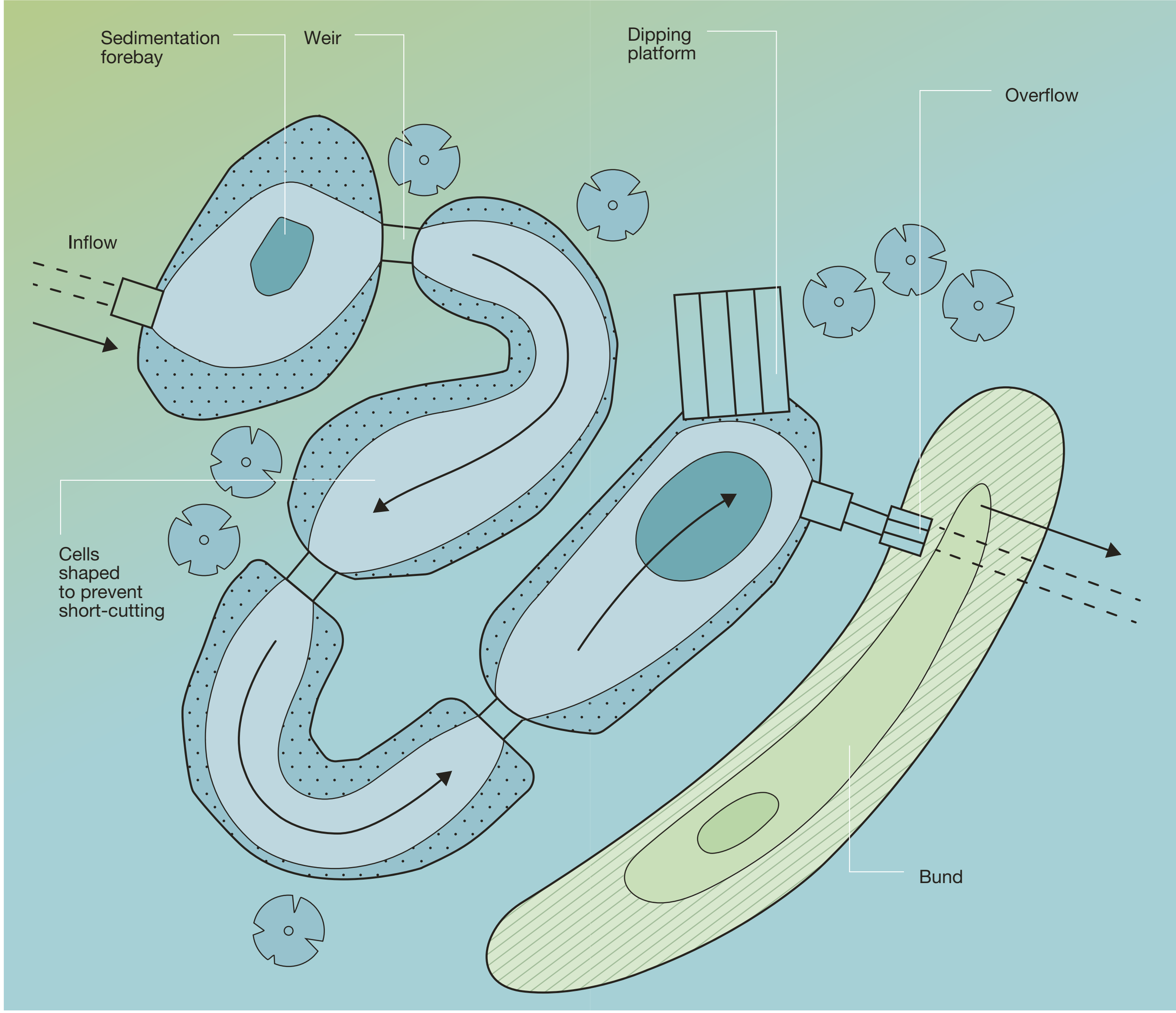
The primary steps are flow control is applied due to the presence of plants which reduce the flow velocity and enhance the hydraulic resistance, easing the flows spread in the wetland.The weirs and pipe connections are responsible for controlling the water levels within the cells. Proper design of the weirs can also provide the secure movement of migratory animals. The flow path is an essential consideration for an effective design. The position of weirs or pipes between cells should ensure the longest journey to maximize the treatment potential.

Design of the macrophyte zone should also consider appropriate proportions and depth, 50-70 cm for extended detention with a suitable base material to retain water (clay). The longitudinal bathymetry should provide a maximum 70cm depth on the edges, slowly growing to 50cm in the central part. While the cross sectional bathymetry is flat. Design of the bathymetry should ensure connections with deeper open water pools with permanent presence of water, being as large as 20%-30% of the total macrophyte area, to host the mosquito predators.

The outflows should provide the water transfer back into the system. Therefore, they should be protected to avoid blockages, and designed such as to be accessible for maintenance and cleaning. Dimensions of outflow should be minimum equal to that of the inflow, and larger for higher flows. Extreme flows should be directed properly away when exceeding the maximum capacity of the wetland.

4. Vegetation Types

The macrophyte zone vegetation should be permanently present with a significantly high density (70-80%) in order to guarantee the functional efficiency. Selection of plant species is another



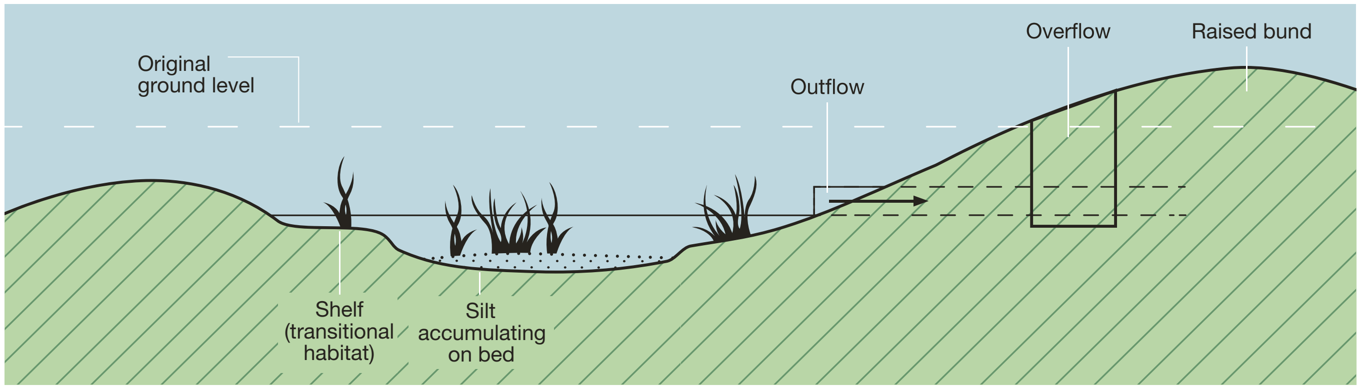
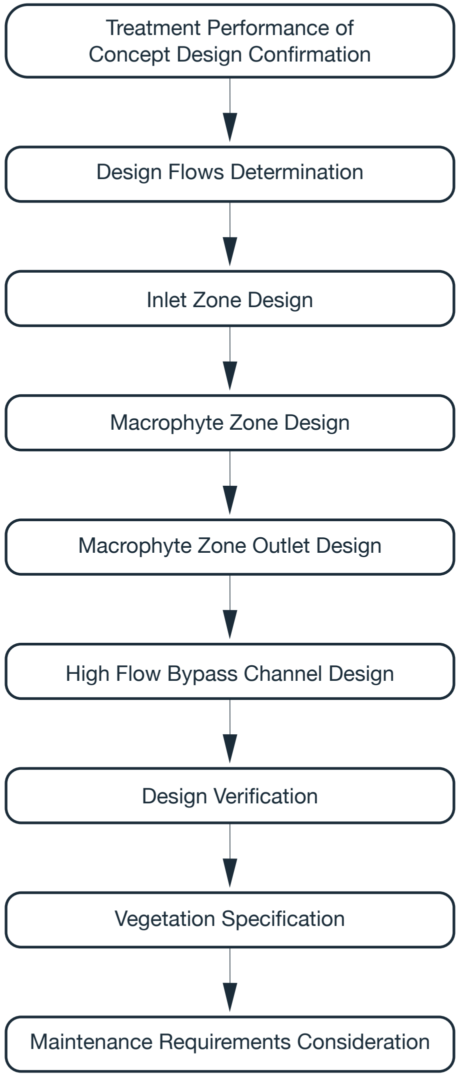


FIGURE 13:
Typical constructed wetland layout with key features identified
Source:Russell,I.,Pecorelli,J.,Glover, A.,2021

FIGURE 14:
Section through wetland cell and raised bund
Source:Russell,I.,Pecorelli,J.,Glover, A.,2021

FIGURE 15:
Wetland Design Process
Source: Constructed Stormwater Wetlands, WSUD Technical Design Guidelines for the Coastal Dry Tropics



essential factor deriving from the hydrologic regime, life histories, physiological and structural characteristics of the wetland plants. In general, non-native, invasive, exotic and deep rooted species should be avoided. However, using a variety of plant species can increase the system resilience, supporting more diversity of local wildlife, while the species and planting density might vary according to the wetland zones and water quality.

Wetland establishment is a relatively quick process, which means it will be able to fully function in a short period of time. However, a lasting quality requires proper management and maintenance, including removal of plants within the rows, cutting down of plants to water level in die-back season, removal of plants and barriers at the inlets/outlets, and removal of invasive plants. Silt management is also essential, although it is not considered a frequent action, being held every 10-15 years. Wetland management is considered significantly low-cost and can be undertaken by volunteers, involving the local community, with proper training, tools and supervision.

4.3. Ecological assessment approaches

Ecological evaluation of the actual situation and various intervention scenarios before the final implementation provides the architects and decision-makers with tangible results. In this regard, various tools have been developed to deliver specific outputs by the collection of related environmental data. This research has detailed out some of the most sophisticated and efficient approaches in the field.

4.3.1.Ladybug Tools

"Ladybug tools are free and open source plugins to support environmental design and education. these tools link the CAD interfaces to a host of validated simulation engines." (ladybug tools 2022). Ladybug, Honeybee, Dragonfly and Butterfly are the main tools Each of them are responsible for different type of analysises. While "Ladybug performs detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design, the "Honeybee creates, runs, and visualizes daylight simulations using Radiance and energy models using OpenStudio and EnergyPlus."
Dragonfly is being utilised to prepare energy simulations on the district level models with Urbanopt along with optimization of renewable with Reopt. urban heat modeling also becomes possible by using Urban Weather Generator.
The preparation and run of sophisticated computational fluid dynamic simulations are conducted by openFOAM which is linked to Butterfly tool. "Butterfly is built to quickly export geometry to OpenFOAM and run several common types of airflow simulations that are useful to building design. This includes outdoor simulations to model urban wind patterns, indoor buoyancy-driven simulations to model thermal comfort and ventilation effectiveness, and much more." (ladybug tools 2022).
Despite the vast range of analysis provided by Ladybug tools, there are still some aspects which are not being considered such as the full coverage of the effects and benefits that can be gained by the implementation of certain greeneries.

4.3.2. i-Tree tools

The i-Tree tools have been developed by the United States Forest Service.It is a free platform and the scope is to “quantify the benefits and values of trees, Advocate for better tree and forest management and Show potential risks to tree and forest health”. Another output is related to carbon offset plans for which the standardized metrics are provided by i-Tree. Environmental justice efforts and related assistance are also part of the tool (USFS, 2022). The main i-Tree tools are i-Tree Eco, i-Tree Landscape, i-Tree Hydro plus, i-Tree Design, i-Tree Canopy, i-Tree Species, and i-Tree MyTree. Each tool discusses some specific benefits of trees to society. Pollution removal, Carbon sequestration and storage, different types of Hydrology effects such as avoided run-off, interception, transpiration along with Building energy effects, the study on Tree bio-emissions and the UV effects of the tree are some important functional analyses for architects which are carried out by i-Tree eco. Besides, the tool covers also analyses of Species condition and distribution, leaf area and biomass, species importance values, along with diversity indices and relative performance. Influence of extreme climate events, annual mortality and adjustments, pest risk analysis and cost benefit analyses are also part of the tool. Classification of the land covered by trees, buildings, roads and any other defined category by the user becomes feasible by i-tree Canopy. Users need to define the types of land on the automatically generated points of the tool. The tool recommends defining 500-1000 points in the study area boundaries to have an accurate output. Ultimately, the tool prepares a report with the percentage of various land coverings and shows the benefits of the tree canopy related to co2 sequestration and storage, air pollution and stormwater. Another tool which is designated In order to "identify priority tree planting and protection areas for climate and social justice efforts" is i-tree Landscape (USFS, 2022).

Some i-Tree tools are being operated using internet browser and google maps, while for instance i-tree eco is designed as software. The main constraint of the utilization of i-Tree tools lies in the fact that the database used for various estimations and simulations is limited to some countries.

4.3.3. LIM approach

"LIM landscape information modelling® is a landscape approach to Building Information Modeling (BIM) which supports the design of nature-based solutions by adding a new dimension to BIM, and steers informed decisions for greener and healthier cities based on a data-driven approach." (LAND, 2022). LIM measures the environmental parameters which are influenced by the landscape projects. It also prepares the simulation of vegetation growth as well as visualizing the effects in the case of different spatial interventions. Consequently, it prepares a sustainability pre-assessment which creates a better understanding of design decisions, approval processes and future maintenance due to the final proposal. Moreover, The results of the measured performances can provide rating systems of sustainability certifications and assessments such as LEED with the necessary information.

Tree information is environmental parameter which includes information such as canopy cover, tree characteristics, time to grow to an ultimate height and allergenic values. Air quality is another considered parameter which studies the data

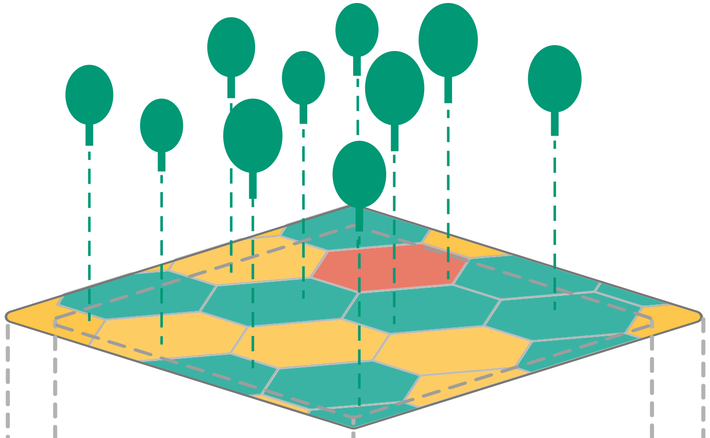


FIGURE 16:
From BIM to LIM
Source: (LAND, 2022)

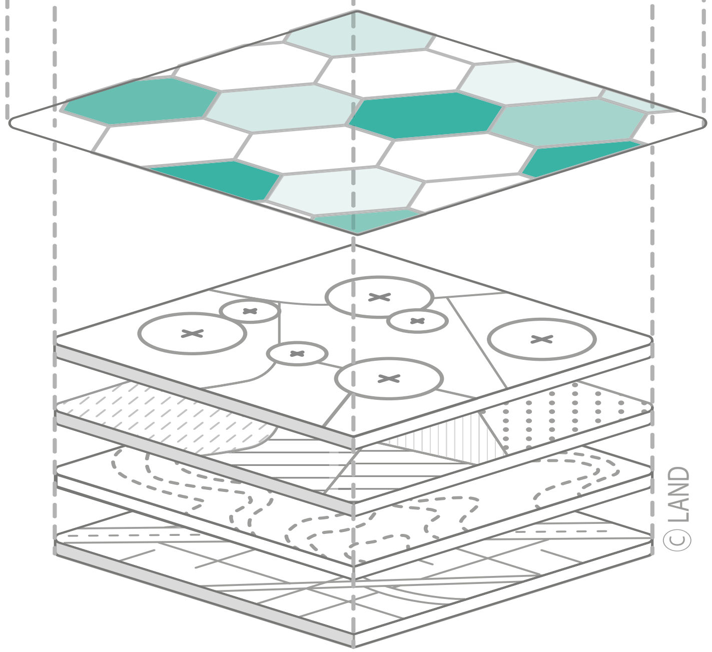
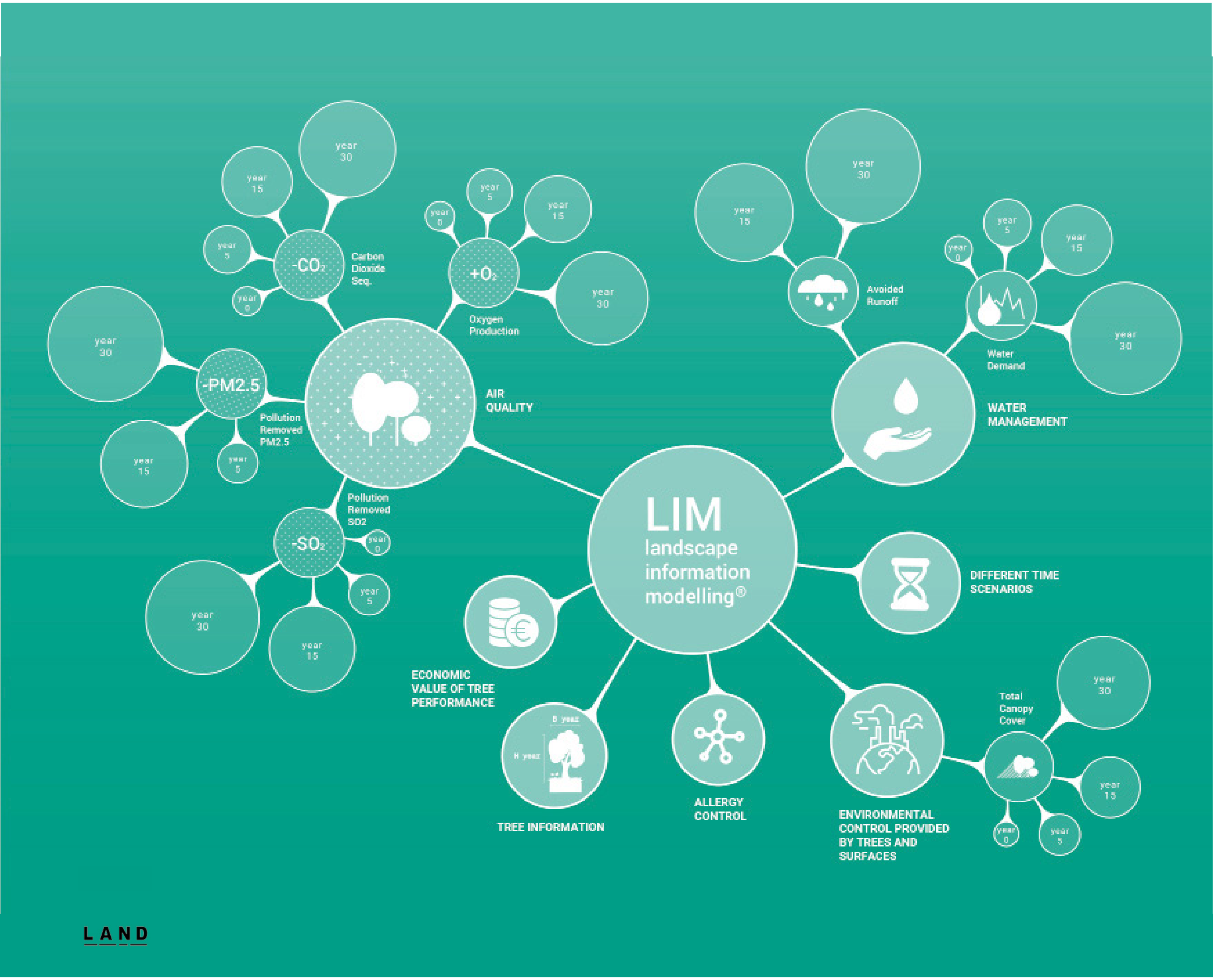


FIGURE 17:
Environmental parameters of LIM approach
Source: (LAND, 2022)



on Carbon Dioxide Storage, removal of different pollutants VOC emissions and oxygen production due to the design proposal. Besides, the daily water demand for the different species and avoided runoff are also part of the analysis. Moreover, various tools being used to monitor and improve the permeability of the surfaces.

The methodology of the LIM approach lies in the Preliminary evaluation of characteristics of the location to define vegetation coverage according to the LIM database also BIM-related information for that specific site. these data are leading to the selection of project-specific LIM strategies. Then a LIM model including the application of environmental parameters in different time spans is prepared. The ultimate phase is the "Creation of sustainability dashboard and reports for final assessment". The final output is a "BIM/GIS Information model, Landscape sustainability dashboard representing variation of environmental parameters over time, Visualisation of performances across different project scenarios and Performance report for sustainability certifications and assessments (LAND, 2022).

4.3.4. Envi_Met

Useful Terminology

Envi-met is the software used in this research in order to study the microclimatic site-specific characteristic of the research site before and after the implementation of proposed adaptation and mitigation strategies. The Envi-met utilization on the site is discussed in detail in chapter six of this research.

This section aims to introduce Envi-met as a microclimate analysing tool beginning by uncovering the key expressed terminologies within the tool to understand the software and its principles.

Term	Definition
Albedo	Ability of a surface that allows it to reflect solar radiation, measured between 0 and 1. (Lopez-Cabeza et. al, 2022).
Computational Fluid Dynamics (CFD)	A branch of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows (Erell et al., 2011)
Emissivity	The ability of the material to emit or absorb radiation (Dryden, 1982)
Evapotranspiration	The total process of water transfer into the atmosphere from vegetated land surfaces, comprising the sum of evaporation and transpiration (Erell et al., 2011).
Mean Radiant Temperature (MRT)	The uniform temperature of an imaginary enclosure (or environment) in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure (Li, 2016).
Microclimate	The climate of a very small space, which differs from that of the surrounding area. Microclimatic conditions within an area in micro-scale are influenced by the physical nature of the immediate surroundings and the climate of the surrounding region (Erell et al., 2011).
Predicted Mean Vote (PMV)	The first thermal comfort indicator for indoor spaces to support the environmental design and particularly to the study of the hygrothermal requirements of mechanically controlled spaces. (Losasso et al, 2020)
Psychological Equivalent Temperature (PET)	A thermal comfort index which is equivalent to the air temperature where the heat balance of the human body is maintained with core and skin temperatures equal to those of the evaluated conditions (Höppe, 1999).
Urban Aspect Ratio	Also known as Height to Width Ratio (H/W), is an adimensional parameter, used as an indicator of the geometry of urban canyons (Losasso et al, 2020).
Urban Canyon	A linear space that represents a street with vertical elements on the sides as walls of the adjacent buildings. Three elements are used to describe the geometry of an urban canyon: height-width ratio (aspect ratio), axis orientation and sky view factor (Erell et al., 2011).
Urban morphology	The study of urban form that examines the formation and transformation of cities, towns and villages (Chen, 2014).

A General Overview

The holistic microclimatic model and approach developed by Envi_Met, make it distinct from the other environmental simulation models available. Different scientific disciplines such as fluid dynamics, thermodynamics, soil science and plant psychology are being calculated by the model. Consequently, all the elements can interact with one another on just one model and reproduce the synergy of the

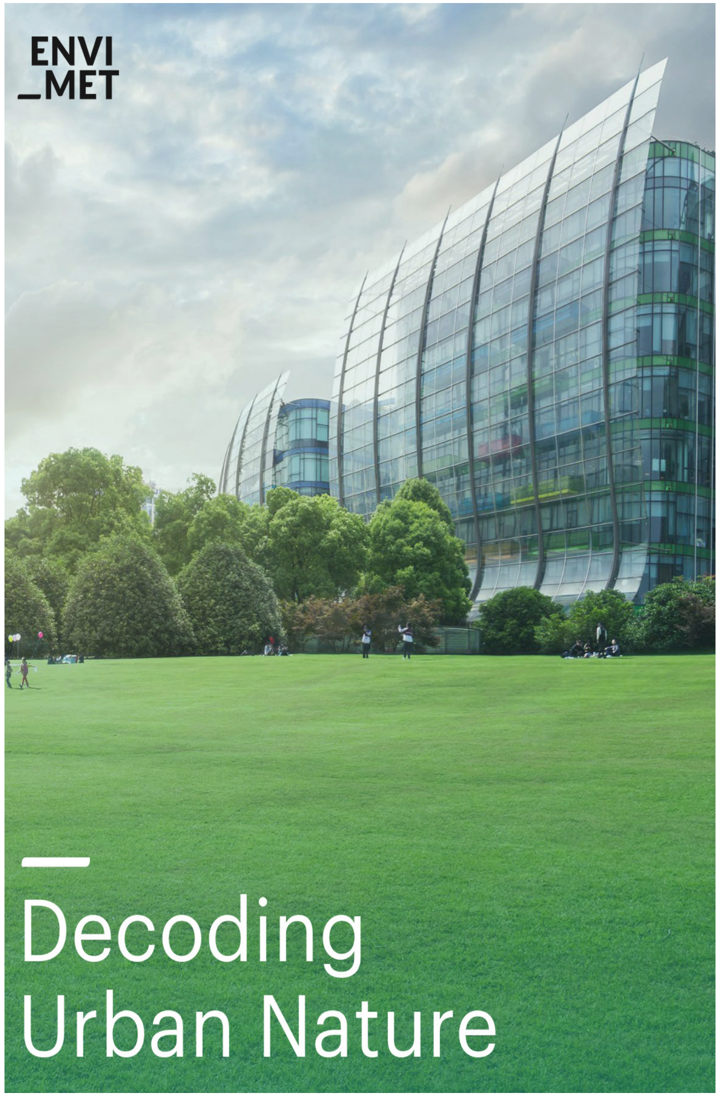


FIGURE 18:
Decoding Nature: Presentation booklet of Envi_met for adaptive cities for climate change
Source: (Envi_Met GmbH, 2017).

real. Cities and health, Wind and sun, Buildings and climate along with Trees and vegetation are 4 main Categories of the environmental assessments and simulations developed by Envi_Met. Air pollution and thermal comfort are presented as concerns related to cities and health. "The pollutant dispersion model of ENVI_MET allows the synchronous release, dispersion and deposition of up to six different pollutants including particles and both passive and reactive gases. Sedimentation and deposition on surfaces and vegetation is taken into account as well as the photochemical reaction between NO, NO2 and Ozone (O3) and the release of (B)VOC through plants." As a result, the dynamics of local pollutant dispersion become evident which leads to the creation of urban streetscapes and green infrastructure to enhance human well-being and air quality. Regarding thermal comfort, steady state and transient thermal comfort conditions are being evaluated holistically through various thermodynamic models in software.Analysis of urban heat islands is also another feature of the tool which consists of a holistic and dynamic simulation of all UHI elements

such as the temperature of the surfaces, wind flow, transpiration of vegetation and soil wetness.
Solar radiation analysis is part of the Wind and sun category. An immediate and comprehensive analysis of the building façades while the environment including vegetation is considered is feasible by solar access modules of Envi_Met. The tool is also able to analyse solar access over a long-term yearly period.
3D system of computational fluid dynamics (CFD) is a feature of the software which demonstrates the movement of energy away from surfaces, and the distribution of air pollutants. It also provides data on comfort and wind risk for humans and greenery.
Analyses related to Building and climate mainly cover the field of building physics. Envi_met provides also efficient and profound analysis regarding the trees & vegetation. Urban trees often suffer from the efficient room for their roots which deteriorates their mechanical properties and sufficient water supply.
The vitality of trees and plants is being monitored to understand feasible interactions within buildings and urban microclimate. Besides, the vegetation is capable to cool down the air in case the temperature of the leaf is lower than that of the air. Software is able to calculate the leaf temperature while the photosynthesis rate, water availability and the local microclimate conditions are also considered.
Another feature is the Envi_Met Tree Pass analysis that studies wind loads, water consumption and growing conditions for trees in various locations to compare them with the plants' needs. therefore various wind risk, thermal stress and water stress analyses can be simulated (Envi_Met GmbH, 2017).

Envi-met modules

Each module and tool included within the software is responsible for a specific part of the modelling and simulation process.
This section embraces the most prominent gadgets of Envi-met. Space module defines the area with a griding system that supports high resolution in terms of spatial and temporal aspects in form of cells which are ranging from 50x50 to 500x500 grid cells in the horizontal direction and 20-50 cells in the vertical direction. Besides, the main urban modelling phase takes place in this module while the three-

dimensional trees can be defined and modelled in the Albero module before being inserted in the space. Modification of the building materials, two-dimensional vegetation, pollution sources and soils is feasible through the Database manager before being utilized in spaces module.

As far as the simulation is concerned, the envi-met guide and envi-met core are the main modules which are responsible for collecting the meteorological data, and setting up and running the simulation. The simulation time can vary according to computer power charactersitcs and and number of selected CPU cores for the calculation process. The Bio-met module is dedicated to thermal comfort analysis through various types of thermal comfort indexes such as PMV, PET, UTCI. Bio-met collects the simulation results related to the atmosphere for delivering a thermal comfort analysis.

All the data related to the simulations and thermal comfort analysis can be visualised in a selective sense in the Leonardo module. chapter 6 of the research discusses how each module has been involved in the microclimatic assessment of the site.

Envi-met Limitations

There are certain constraints in the simulation and calculation processes considering the software's limitations. For instance, related to the wind velocity and its direction which remains constant during the period of simulation. Moreover, in the case of having an input wind speed higher than 2 m/s, the accuracy of the model suffers. As far as turbulence calculation is concerned, the model presented in the software is k –e closure which tends to hyperbolize the turbulence production in areas with high acceleration or deceleration and it becomes more tangible in case of modified airflow by barriers. another limitation is related to the long-lasting computation time as a result of the comprehensive and detailed calculation of urban scale. Perhaps decreasing the model resolution on the z-axis could be a catalyst to reduce the required time up to a point. In spite of facing certain constraints, Envi-met remains a distinguished tool utilized for urban microclimatic assessment. (Sharmin et al., 2017).

4.4. Adaptive reuse

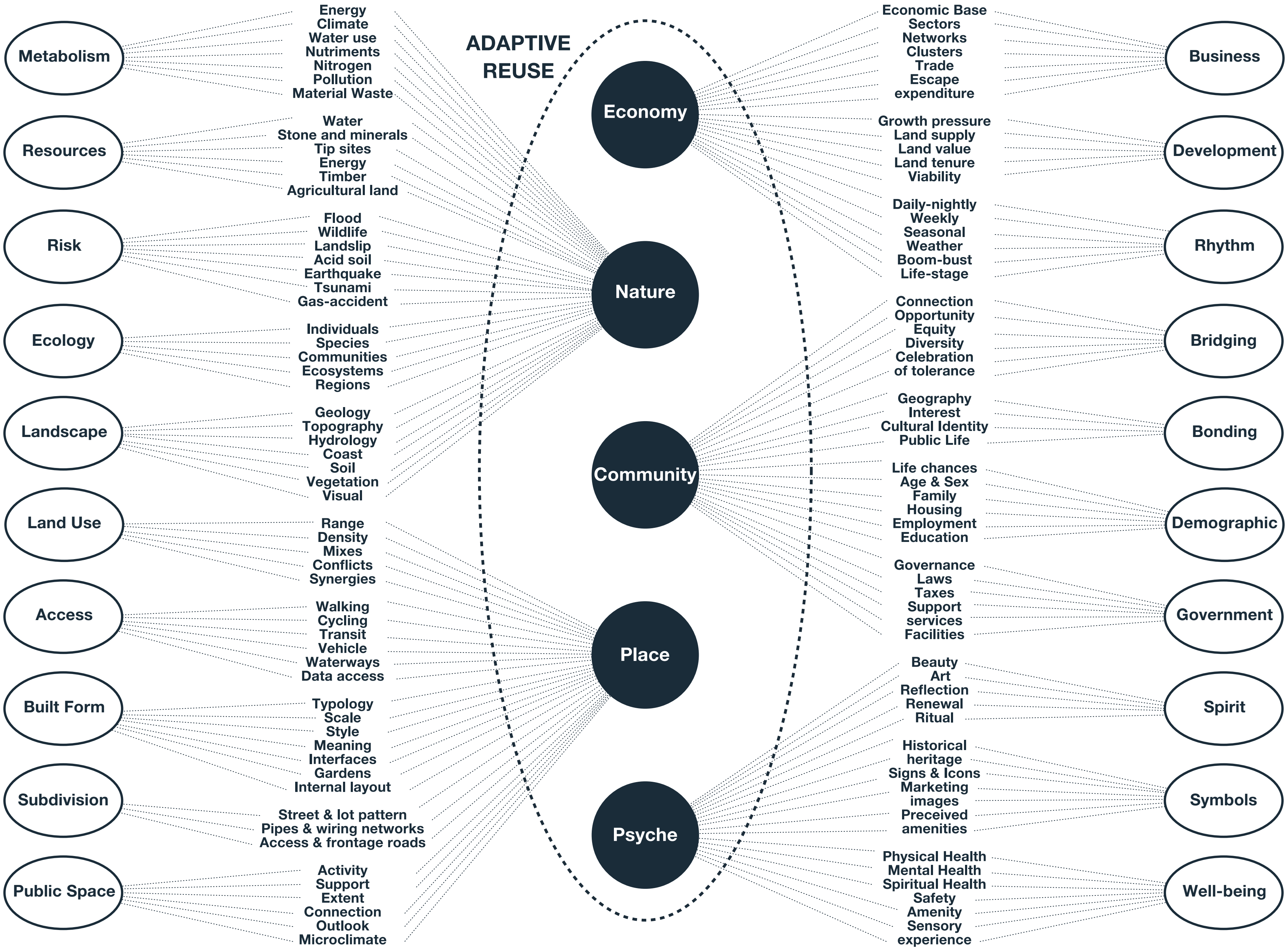
The concept of adaptive reuse refers to the recycling, conversion and reusing of an existing building, by adopting a purpose other than its original one. (Caves, R.W., 2004). In recent decades with consecutive economic and environmental crises as well as the social concerns for the new normals, adaptive reuse has become a promising strategy for promoting the optimal performance of the buildings as components of urban regeneration, being an alternative to new construction in terms of sustainability and a circular economy (Sanchez, B., Haas, C., 2018). The concept, therefore, involves a wide range of benefits, including environmental, social and economic aspects. From the environmental point of view, adaptive reuse contributes to the reduction of embodied energy, construction and demolition waste, emissions and urban sprawl, meanwhile promoting water and energy efficiency, materials and resources, and urban regeneration. Regarding the social aspects, adaptive reuse retains the link between the past and the future, maintaining the heritage and identity, and assisting the development of neighborhoods and communities. In this respect, it also results in a significant reduction in costs for the population. Furthermore, active involvement in urban society leads to added social value. While the economic benefits are associated with reduced investment costs, taxation policies, market value, circular economy and future development strategies.

In this context, urban industrial brownfields have been brought to attention with the aim of transforming them into living urban components following the new patterns of usage and lifestyle.

"New patterns of usage and lifestyle often develop at precisely those locations in the city in which it is possible for people to appropriate and modify spaces" (Baum, M.,Christiaanse, K., 2012).

The specific features, legacy and context of these derelict sites, along with the architectural language, specific spatial qualities, generous inclosed and open spaces ensure their powerful potential for redevelopment with a flexible open context for current and future needs, often exceeding the limits of a single building, transferring the concept into a more holistic urban context, while incorporating

FIGURE 19:
Objectives of adaptive reuse by Townsend Source: Townsend 2015; Redrawn by the author.


ADAPTIVE REUSE
Economy
Nature
Community
Place
Psyche
Metabolism
Energy
Climate
Water use
Nutriments
Nitrogen
Pollution
Material Waste
Resources
Water
Stone and minerals
Tip sites
Energy
Timber
Agricultural land
Risk
Flood
Wildlife
Landslip
Acid soil
Earthquake
Tsunami
Gas-accident
Ecology
Individuals
Species
Communities
Ecosystems
Regions
Landscape
Geology
Topography
Hydrology
Coast
Soil
Vegetation
Visual
Land Use
Range
Density
Mixes
Conflicts
Synergies
Access
Walking
Cycling
Transit
Vehicle
Waterways
Data access
Built Form
Typology
Scale
Style
Meaning
Interfaces
Gardens
Internal layout
Subdivision
Street & lot pattern
Pipes & wiring networks
Access & frontage roads
Public Space
Activity
Support
Extent
Connection
Outlook
Microclimate
Business
Economic Base
Sectors
Networks
Clusters
Trade
Escape
expenditure
Development
Growth pressure
Land supply
Land value
Land tenure
Viability
Rhythm
Daily-nightly
Weekly
Seasonal
Weather
Boom-bust
Life-stage
Bridging
Connection
Opportunity
Equity
Diversity
Celebration
of tolerance
Bonding
Geography
Interest
Cultural Identity
Public Life
Demographic
Life chances
Age & Sex
Family
Housing
Employment
Education
Government
Governance
Laws
Taxes
Support
services
Facilities
Spirit
Beauty
Art
Reflection
Renewal
Ritual
Symbols
Historical
heritage
Signs & Icons
Marketing
images
Preceived
amenities
Well-being
Physical Health
Mental Health
Spiritual Health
Safety
Amenity
Sensory
experience

all the available resources being the buildings, infrastructure and the people involved.

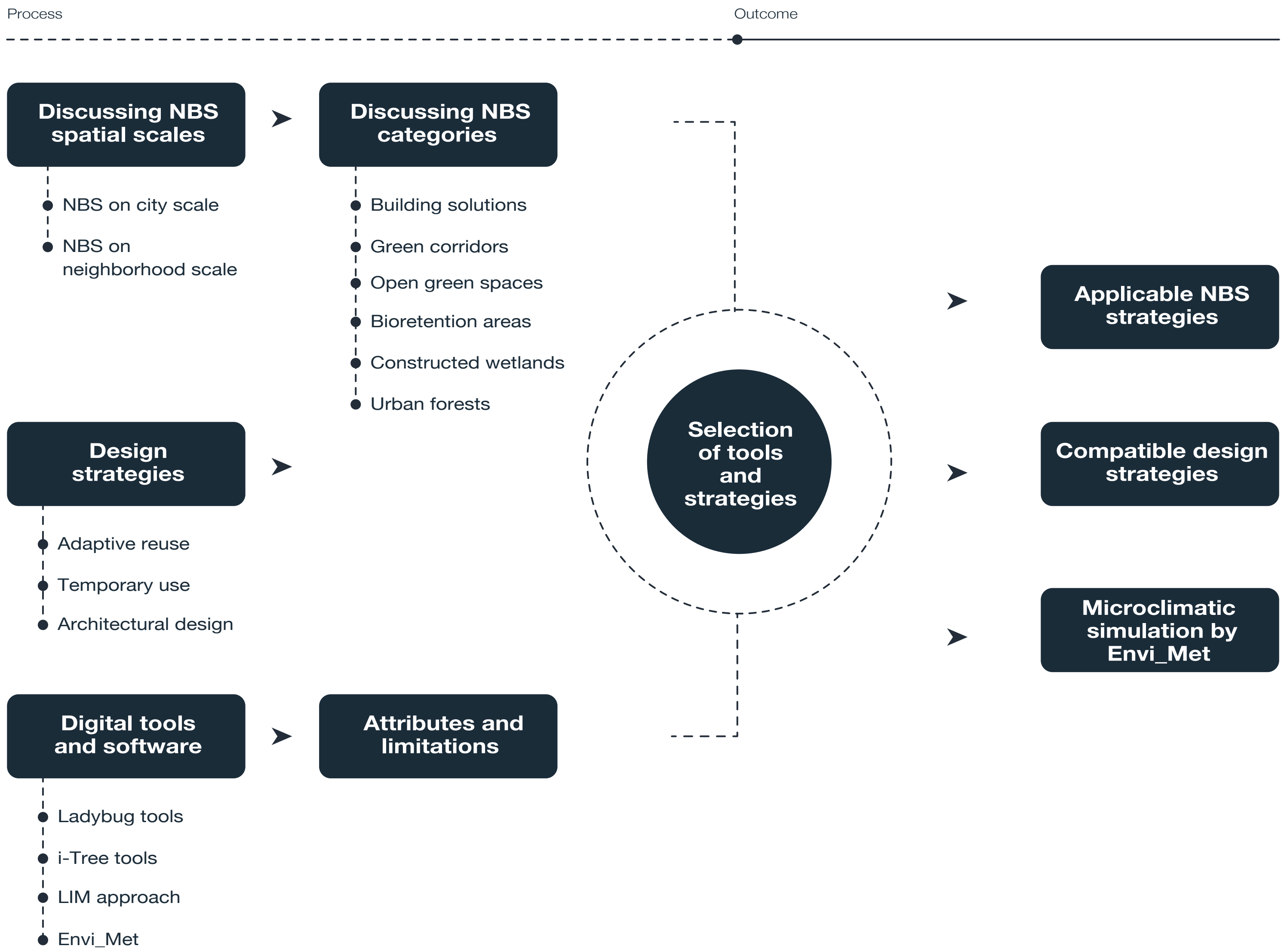
While pleading the cost effectiveness of the adaptive reuse projects, possible pollution remediation processes turn out to be among the most inefficient constraints. Despite the discouraging approach, the remediation process remains a widely discussed matter as an inseparable parallel to adaptive reuse process. "Decontamination can and has to be incorporated in the reuse process- for instance, by defining a development timeline that allows the use of slower but cheaper techniques such as phytoremediation, or by laying out new uses according to the cleaning requirements imposed on existing spaces'' (Robiglio, M., 2017). Generally, the remediation actions aim to provide protection against pollutants for the people and the environment. Therefore, remediation strategies and principles have been widely discussed around the world. Having the fact that the European Union has assigned each member to develop its own standards and laws to regulate the remediation of brownfields, with no common directiv, the Italian legislation sets a procedure which includes steps such as site identification and characterisation, risk assessment, the evaluation of different risk management strategies, the implementation of a selected management strategy, assessment and monitoring (The law 9 December 1998 n. 426, its internal organ, the ISPRA, the Italian acronym for: Institute for Environmental Protection and Research).

The recent integrated methodology has defined “Adaptive remediation” as a perspective that "implies a deep knowledge of the site conditions in order to decide what kind of reuse should be adopted and to minimize the remediation cost, being equal, of course, to the level of safety. Adaptive remediation is strictly carried out together, in time and space, with an overall redevelopment plan" (Ingaramo, R., Lami, I.M., Robiglio, M., 2022). The same methodology has articulated the process in four distinct phases, namely:

1. Site analysis, including the survey of existing abandoned buildings, mapping of the pollutants, verification of the pre-existing projects, public and private parties interest.

2. Identification of the remediation map for the various parts into which the site can be divided according to the pollutants.
3. Development of an adaptive reuse project, integrated with the remediation actions and the hypotheses of the real estate valorisation of the area.
4. Construction of an incremental architecture and value creation strategy, subdivided into phases, adaptable according to the evolution over time.
Consequently, adaptive reuse of contaminated industrial areas is a long-term process, which for the best performance should be accompanied with economic feasibility and social integration strategies.
The whole process includes:
1. Exploring and assessing the site
- location
- scale of intervention
- maximizing the potential of existing structures (load bearing, high ceilings, intermediate levels, covered streets, squares, ramps, public space.
- finding the most convenient solution for the negative potentials (contamination, remediation, etc.)

2. Identifying a new vision
- linking the existing infrastructure to the local and global trends and challenges
- linking the past and future
- Mixed use
3. Identifying the partners
- Integration of the community
- Identifying the initial partners
- According to the site conditions, create a fitting flexible concept, staying open for new stakeholders.
4. Design
- Using the existing spaces as soon as possible, starting from the safest and most convenient one.
- Designing with adaptive remediation
- Creating common spaces
- Dividing the space accordingly contributing to cost effectiveness
- Incorporating art and landfill materials contributing to cost effectiveness
- leaving space and/or possibility for expansion, considering the design a never ending process.


Process
Outcome
Discussing NBS spatial scales
NBS on city scale
NBS on neighborhood scale
Discussing NBS categories
Building solutions
Green corridors
Open green spaces
Bioretention areas
Constructed wetlands
Urban forests
Design strategies
Adaptive reuse
Temporary use
Architectural design
Digital tools and software
Ladybug tools
i-Tree tools
LIM approach
Envi_Met
Attributes and limitations
Selection of tools and strategies
Applicable NBS strategies
Compatible design strategies
Microclimatic simulation by Envi_Met

CHAPTER 5
LESSONS LEARNED

5.1. Halle Pajol, Rosa Luxemburg Garden

The project is a public railroad space, which is stretched along the railroad of the Gare de l'Est train station of Paris in France, incorporating a covered garden under the structure of the former market hall of the Halle Pajol, and an open garden facing the road and the built urban fabric on the northern side. The market building itself has been restored by Françoise Hélène Jourda, and is transformed into a multifunctional spot including a youth hostel, services, businesses and municipal library.
The projected gardens are equipped with public

Location	*Paris, France*
Construction Year	*2007-2014*
Area	*9.500 mq*
Architects	*IN SITU*
Client	*City of Paris*
Location	

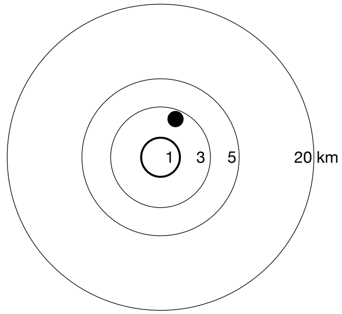


FIGURE 1:
The aerial view of Halle Pajol, Rosa Luxemburg Garden
Source: https://landezine.com/rosa-luxemburg-garden-by-in-situ-architectes-paysagistes/

FIGURE 2:
Rosa Luxemburg Garden, Floor plan
Source:https://landscape.coac.net/halle-pajol-rosa-luxembourg-garden

FIGURE 3:
Halle Pajol, Before and after intervention
Source:https://landscape.coac.net/halle-pajol-rosa-luxembourg-garden

furniture, green and recreation areas, as well as playgrounds, while the principal path is accompanied by Scots pines and ash trees.

On the southern side, the covered garden, shade garden and white garden, expand under the metallic framework of the former market, which are transformed to carry photovoltaic power plant.

The roof structure is also adapted to collect rainwater and store it in the pools of aquatic gardens along the structure. These are meant to irrigate the planted areas and flowerbeds, which mimic the traces of the old railroad tracks.

"Ground cover plants, ferns, bushes, grasses, climbing plants and shrubs form a milieu and an atmosphere of forest undergrowth within the shade of the vast industrial structure. It is a calm and peaceful oasis of vegetation that abuts the Gare de l'Est" (IN SITU).

The two panoramic decks on the edges of the garden are pointed out above the landscape and are projected to act as viewpoints to the unobstructed horizon exhibiting the colorful trains transiting on the Gare de l'Est railway.

The project cost has been reported as 356 €/m².

5.2. Paramit Factory: Factory in the Forest

This electronics manufacturing plant is conceived as a "forest that penetrates, surrounds & steps over the building creating maximum contact with nature, green, breeze, scent, sound, touch".(Design Unit Architects Sdn Bhd)

The integration of nature in between the internal and external spaces of the site create the interconnection as well as protection against the hot and glaring tropical sun, meanwhile providing spaces for outdoor meetings, breaks etc., on the green canopies and roof gardens. The greenery has a role to play in the separation of functions as well, as it does for the production, office and break areas.

The applied materials are limited to reinforced concrete, steel structure, glazing and landscape. However, the determined direction of design provides enormous diffusion of natural daylight in the entire space of the factory, supporting the plants and creating a stimulating & meaningful working environment for the employees, meanwhile, reducing dependency on artificial lighting. The internal yards are shaded with louvered canopies providing solar protection during the hot hours of the day. Besides,

Location	*Penang, Malaysia*
Construction Year	*2017*
Area	*15.000 mq*
Architects	*Design Unit Architects Sdn*
Client	*Paramit Malaysia*
Location	

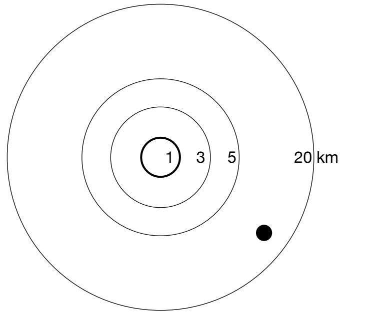


FIGURE 4:
Paramit Factory
Source: https://www.archdaily.com/947771/factory-in-the-forest-design-unit

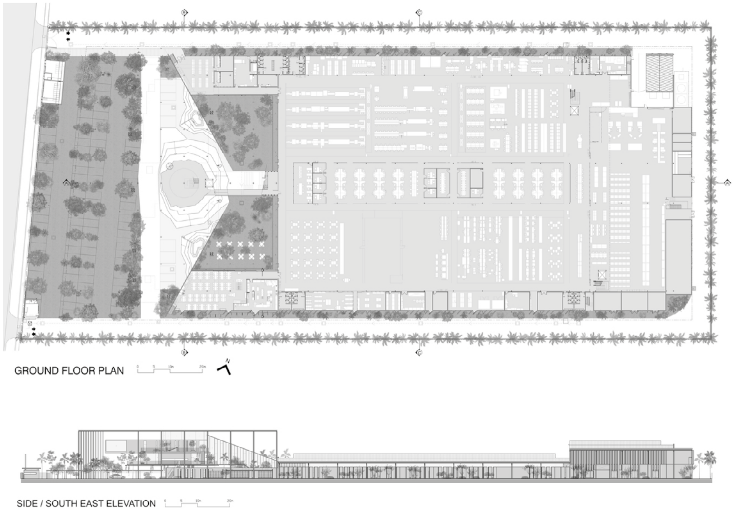
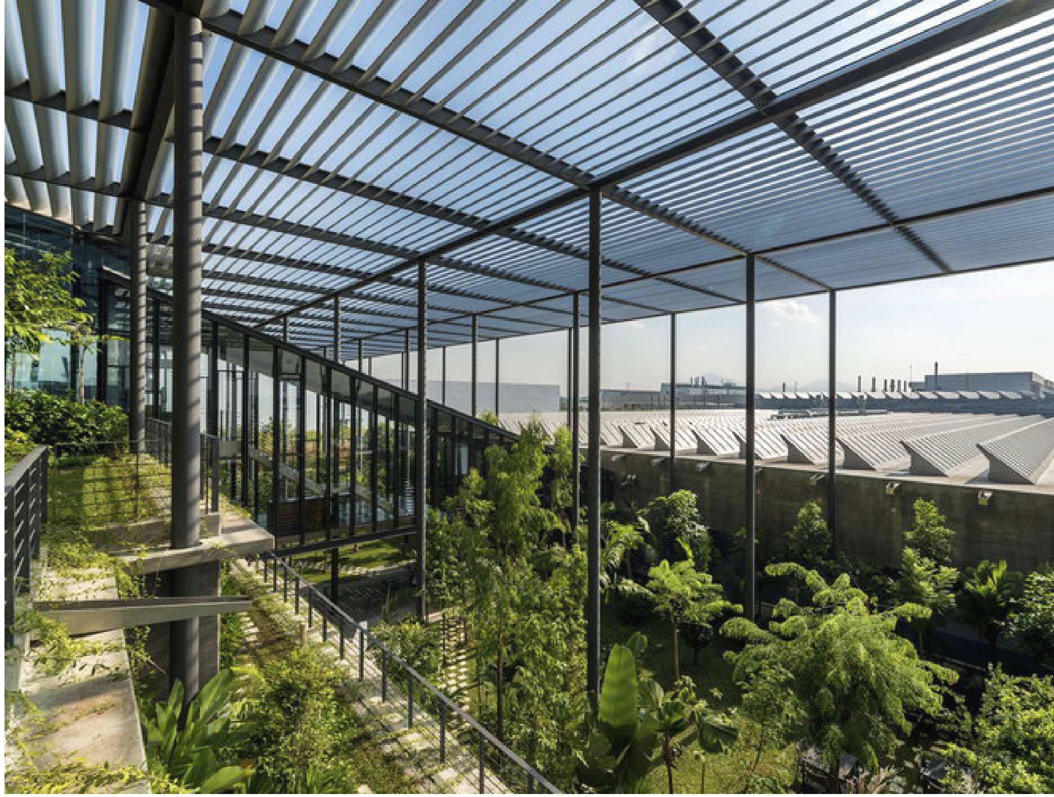


FIGURE 5:
Paramit Factory, floor plan and section
Source: https://www.archdaily.com/947771/factory-in-the-forest-design-unit



chilled water floor slab cooling & cutting-edge air-conditioning technology, with embedded PEX pipes, cool down the slabs to about 21°C, twice reducing the energy consumption for temperature regulation. The internal lighting is however adjusted by LED suppliers to simulate a dimmable level of natural light for individual task lighting.

Having all the above mentioned points in mind, the project is considered a brilliant case study, which responds to sustainability aspects and climate change by energy efficiency, water efficiency, daylighting and biophilia.

FIGURE 6:
Paramit Factory internal spaces
Source: https://www.archdaily.com/947771/factory-in-the-forest-design-unit

5.3. Botanical Train-station

The project is a part of Madrid rail station expansion by Rafael Moneo. In the original building the train platforms were partly covered by a roof in the form of an inverted hull with a height of approximately 27 meters and length of 157 meters. The steel and glass roof spreads between two brick flanking buildings.
The railway complex was expanded during the time, until 1985, when the complete remodeling project began, followed by the exclusion of the original building from servicing as a terminal, and converting it into a concourse with shops, cafés, and a nightclub.
The 4,000 m2 concourse has also been given a new function, a stunning covered dense tropical garden with botanical species and fish from Africa, Asia, America, and Australia. It includes indoor and outdoor landscaping of the station with 6,403 units of plants of 151 different tropical and subtropical species; the aquatic fauna of the pond; irrigation systems, and the “artificial mist”.
The complex is an outstanding case study of infrastructure transformation, urban green, restorations, adaptive reuse and water features.

Location	*Madrid, Spain*
Construction Year	*1993*
Area	*4.000 mq*
Architects	*Rafael Moneo*
Client	*Adif*
Location	

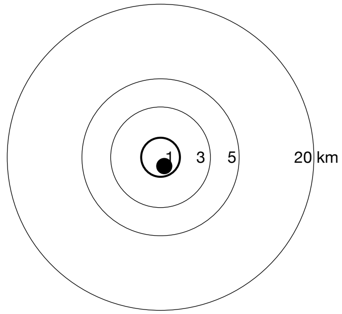
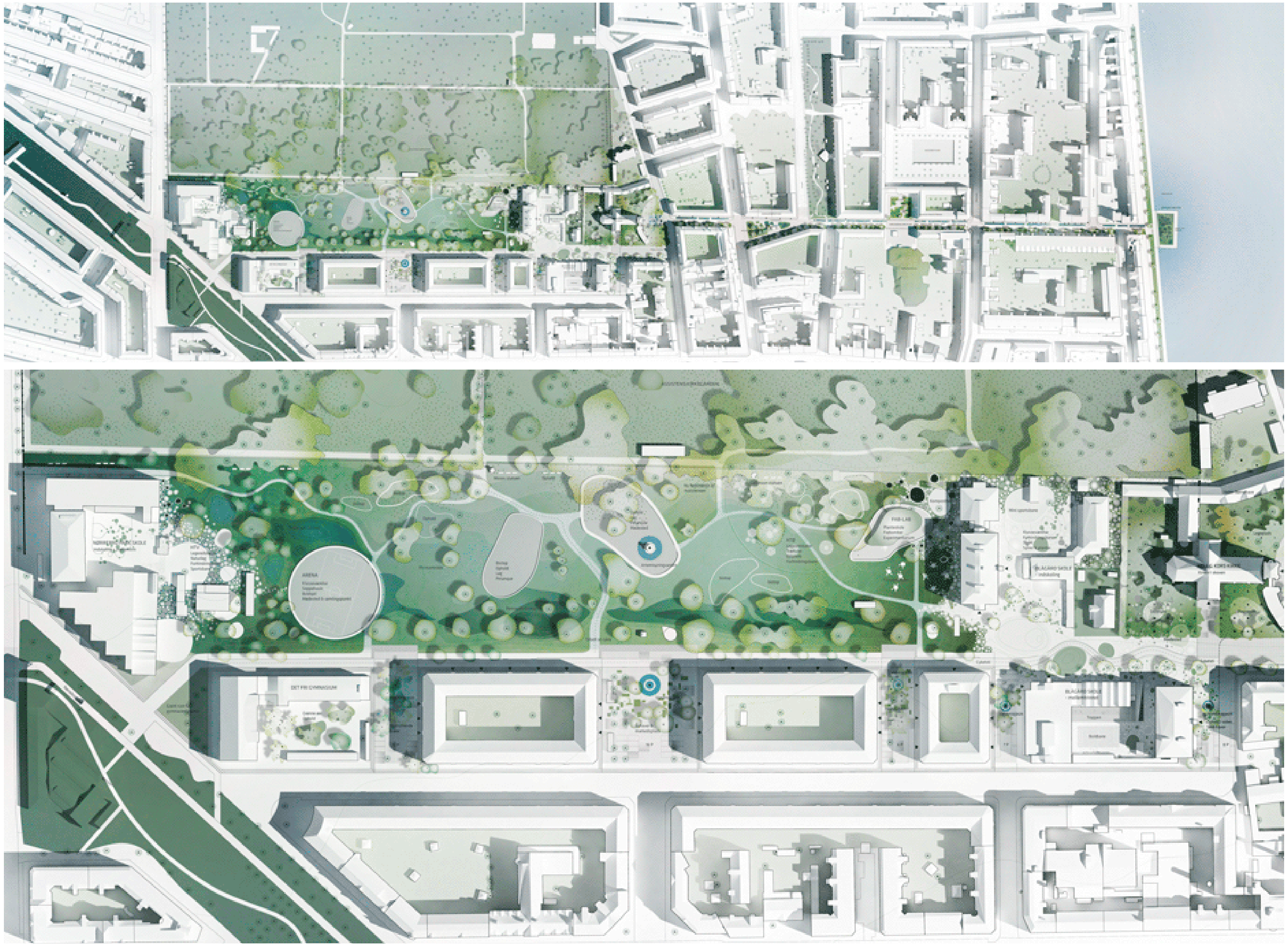


FIGURE 7:
Madrid atocha railway station
Source: https://rafaelmoneo.com/

FIGURE 8:
Madrid atocha railway station
Source: https://landezine.com/botanical-train-station/

FIGURE 9:
Madrid atocha railway station
Source: https://landezine.com/botanical-train-station/

5.4. Hans Tavsen’s Park and Korsgade



Location	*Copenhagen, Denmark*
Construction Year	*2016 — 2023*
Area	*85.000 mq*
Architects	*SLA*
Client	*The City of Copenhagen*
Location	

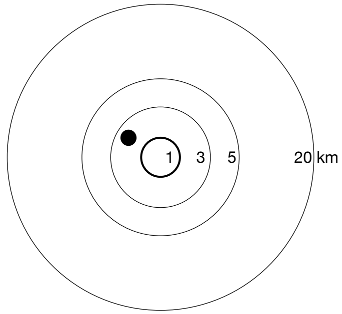


FIGURE 10:
Hans Tavsen’s Park and Korsgade water harvesting system
Source: https://www.sla.dk/cases/hans-tavsens-park-and-korsgade/

FIGURE 11:
Hans Tavsen's Park and Korsgade water harvesting system
Source: https://www.sla.dk/cases/hans-tavsens-park-and-korsgade/

The Soul of Nørrebro is a network of sunken basins and water-purifying planting project.The 160 million project has devised a corridor of "blue-green" spaces consisting of a mixture of planting and water pools, linking the park and lake.The project aims to improve the local microclimate and provide a natural solution to deal with flood provoking conditions such as cloudbursts, flashes of heavy hail.

"Our solution is based on creating a robust city nature that both solves the specific problem of handling torrential rain to avoid flooding, while at the same time creating a new and coherent series of urban spaces that offer stronger social community, greener and more natural experiences, and new creative opportunities for all Copenhageners." (SLA)

In dry season the sunken basin will act as a garden while in wet season it will support the retention area for rainwater. The channels along the Inner Nørrebro will guige the filtered water into the Peblinge Lake.

The project is a clear illustration of climate adaptation in cities, while bringing together the technical and social aspects, an innovative solution with a narrow focus on improving water quality, life quality and ecosystems in Copenhagen.

5.5. Bosco Verticale

The vertical forest (Bosco Verticale) of Milan is part of a more expanded preliminary master plan, realized in 2014. Replacing a former industrial building the project consists of two residential towers of 80m and 112m. It is a brilliant illustration of the integration of greenery in architectural design and creating a dialogue between nature and everyday life, offering verdant balconies as a part of living spaces on all levels for the apartments.
Furthermore, developing the concept of replacing some traditional building materials with plants appears to be affecting human well-being, environmental improvement, and urban biodiversity as a step forward toward the future design of green towers. In this respect, the project is awarded by vaious awards including the International Highrise Award 2014, CTBUH award for the Best Tall Building Worldwide 2015, and RIBA Award for International Excellence 2018.
The selection of plants has been developed through an observation and determination process to sort out the most compatible and resilient species, considering various environmental, plant-specific

Location	*Milan, Italy*
Construction Year	*2014*
Area	*28.134 mq*
Architects	*Boeri Studio*
Clients	*Hines Italia & COIMA SGR*

Location

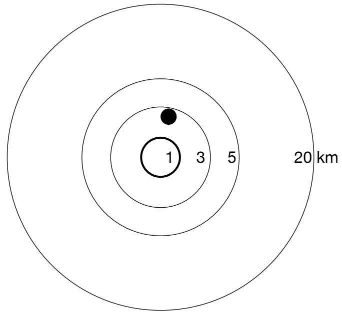


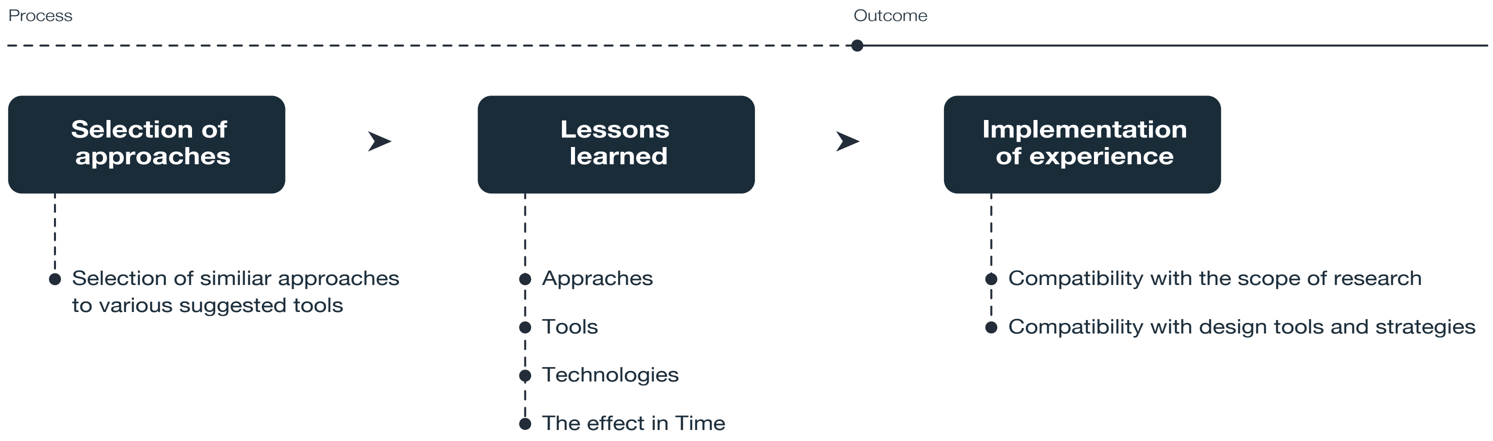
FIGURE 12:
Bosco Verticale
Source: RIBA https://www.architecture.com/

FIGURE 13:
Bosco Verticale Construction
Source: RIBA https://www.architecture.com
https://inhabitat.com/

FIGURE 14:
Bosco Verticale Drawings
Source: RIBA https://www.architecture.com/

and structural conditions. The implemented vegetation which includes almost 17,000 trees, shrubs, and plants, provides the equivalent greenery to 1,500m² over an urban surface. These plants are carefully selected among the most robust 80% of plants that have successfully passed the testing process.

The project has been taken as a significantly relevant case study with similar features of regeneration of the former industrial area, green residential tower, and the selection and implementation of plants in vertical gardens.


Process
Outcome
Selection of approaches
Lessons learned
Implementation of experience
Selection of similiar approaches to various suggested tools
Appraches
Tools
Technologies
The effect in Time
Compatibility with the scope of research
Compatibility with design tools and strategies

CHAPTER 6
REGENERATING FORMER OSI-GHIA INDUSTRIAL SITE

Where and why?
Project area: Features and challenges

The project site is located in the city of Turin in Italy. Being the former capital city from 1861 to 1865, it has been among the leading European political centers. Later in the 20th century, Turin became one of the important Italian industrial poles, flourishing during the Italian economic boom, and becoming the "Automobile Capital", while hosting some of the major Italian automotive industries, such as FIAT.

Industrialization of the city led to further development of the urban area, almost tripling its population, due to the immigrated workforce, reaching 1.2 million in 1971. Furthermore, the city experienced a significant expansion of urban infrastructure and the built environment with an outstanding portion of industrial buildings among them.

The 1970s and 1980s industrial crisis, however, did not make an exception for Turin. Most of the industrial giants were led to closure or shrinkage, consequently, resulting in unemployment and a sharp loss in population, losing more than one-fourth of it in this period. This retrogression left behind numerous abandoned industrial areas, buildings and housing stock to an obscure destiny.

Apparently, the long term population decline was then followed by a slight increase in the beginning of the 21st century reaching 900,000, while the city was brought back to attention, becoming a destination for thousands of students, tourists and various international events such as the 2006 Winter Olympic Games and the 2022 Eurovision song contest.

In recent times, being integrated into the general character and the contemporary shape of the city, these industrial infrastructures are often reinvented and regenerated, hosting new functions or becoming large public spaces. There are several examples of reusing former industrial areas and buildings as university campuses, museums, commercial and public spaces in Turin. Nevertheless, there are still a great number of abandoned industrial areas, which seem to be "disqualified", each for a specific range of grounds.

The former O.S.I.-Ghia industrial area is among the areas which have undergone many critics and discussions to find its proper adaptation to the

FIGURE 1:
Panoramic view of turin
Source: Fabio Lamanna

contemporary urban fabric. Despite multiple tenders, the potential of the area does not seem to fulfill the expectations of the investors for a refurbishment project.

This research discusses the most significant obstacles that the area struggles with, aiming to specify certain objectives and coming up with adequate development patterns, with a narrow focus on the following spheres:

Firstly, the isolation of the area due to lack of the appropriate urban links limits the perspective of developing a successful viable project. Secondly, due to its former use the area is subjected to profond remediation and removal of the industrial contamination, which requires an extra investment and the costs might be extremely high depending on the chosen methods. Finally, having persuasive solutions for the previous points, a proper selection of new functions considering variations of adaptive reuse, partial dismantling and integration of new structures can lead to development of an attractive master plan for various stakeholders and investors.

The following sections will represent more details on these topics.

Historical Analysis

The former O.S.I.-Ghia area is on the western bank of the Po River, between Crocetta and San Salvario neighborhoods. Initially surrounded by ranches the area was located outside the boundaries of the city (figure 2), until the beginning of the 19th century, when the demolition of city walls contributed to gradual expansion of the city infrustructures and the built stock (figure 7). From the southern side long tree-lined avenues were extended to the royal palaces, while the former southern gate was replaced by a square which later was sealed by the Porta Nuova train station. By this time The Kingdom of Savoy had started building railways. Turin-Genoa railway built by Luigi Ranco and Turin-Milan railway built by Thomas Brassey opened in 1845 and 1856 respectively. In fact, the construction of these railways formed the triangle shaped area (figure 3), which was later occupied by industrial buildings. However, untill the end of the 19th century the only significant building nearby was the Mauriziano hospital 1881-1885 (figure 4). In 1908 the Gaia-Garrone foundry was the first to build its headquarter, initiating the industrial footprints in the area between Savonarola Street,

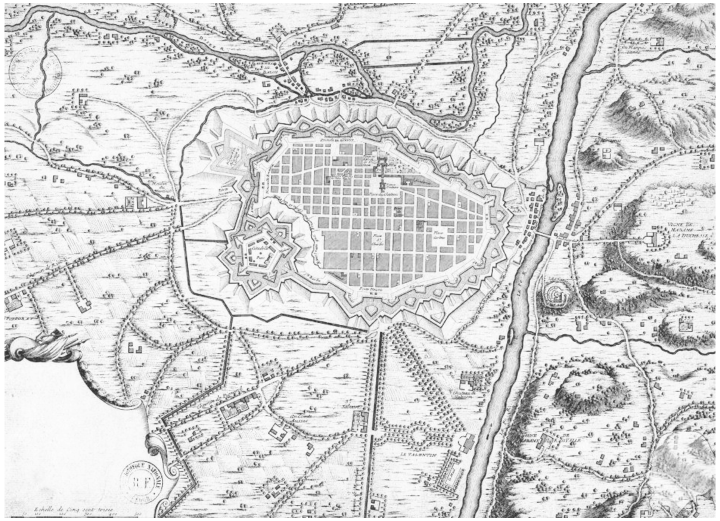


FIGURE 2:
Map of Turin, by Antoine Coquart 1700.
Source: Atlante di torino

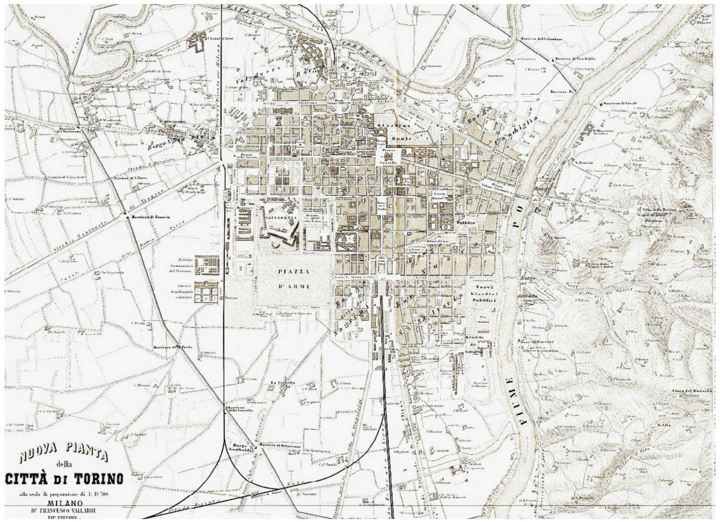


FIGURE 3:
Map of Turin,1869.
Source: Central Civic Library,
Cartografico 8 / 10.30

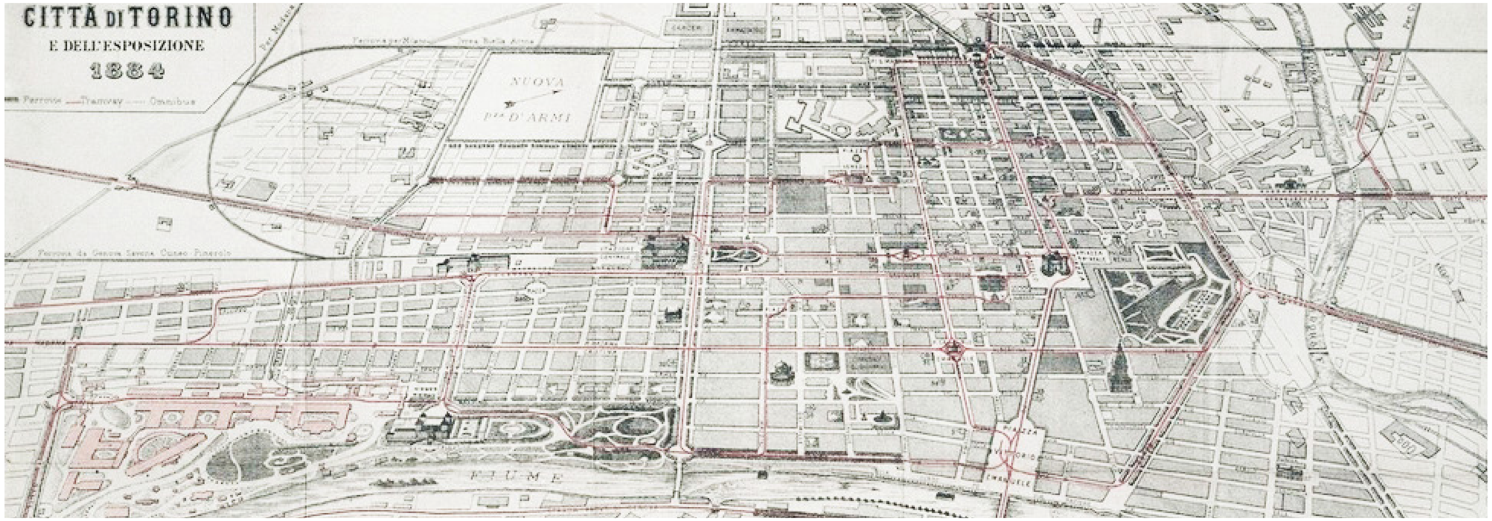


FIGURE 4:
Perspective plan of Turin 1884.
Source: Museo Torino

Roccabruna Street, Bertini Street and Paris Avenue (Osi West). A two story pitched roof building and a single story flat roof one were designed by Eng. Della Beffa, to host the administration and storage (figure 8). The most significant expansions of the buildings started since 1915 with the construction of the temporary roof above Roccabruna Street (ASCT, Pratica Edilizia n°0330, 1915), followed by realization of the first out of five spans of 3 story building facing Bertini Street (figure 10) by engineer Porcheddu simultaneously involved in the design of Fiat Lingotto

FIGURE 5:
Turin-Genoa railway view toward south,1924.
Taken from overpass of Corso Sommeiller.
Source: http://www.mqcvisions.net/Torino-Sparita/

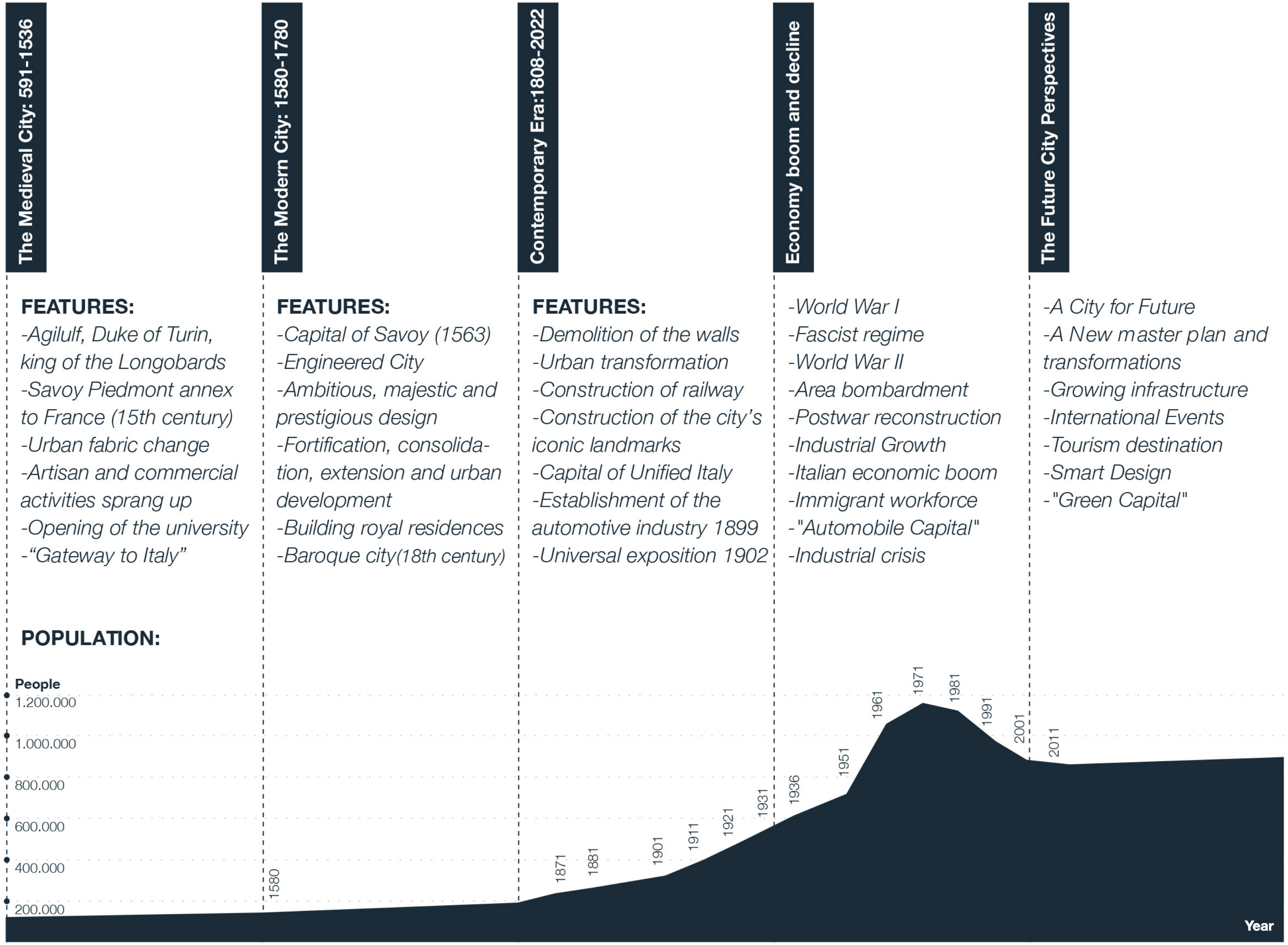


FIGURE 6:
Historical eras and population of Turin.
Source: Italian National Institute of Statistics

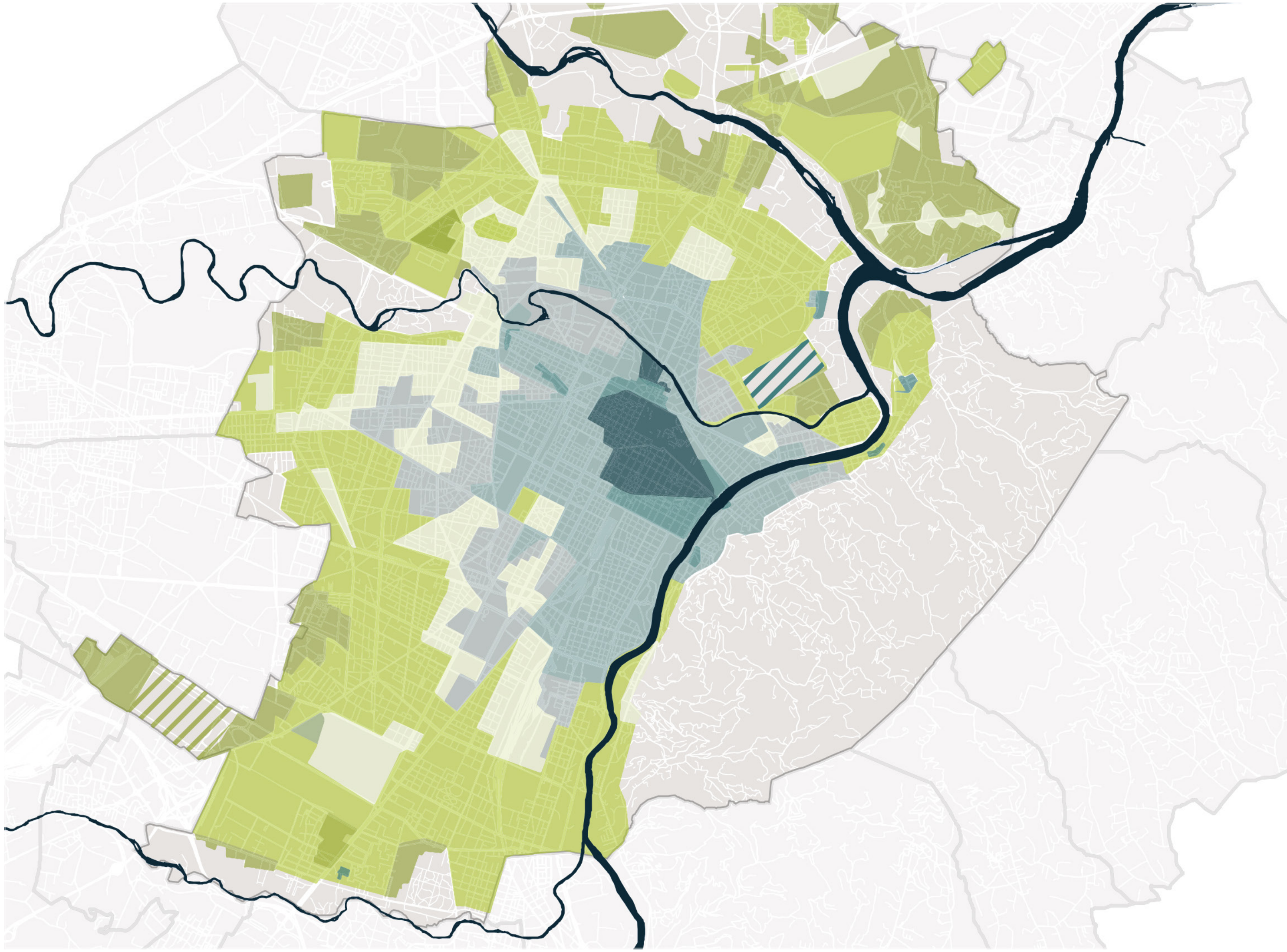


FIGURE 7:
Built areas in various periods, 2018 data.
Source: Elaborazione rapporto rota su fonti storiche varie

LEGEND

- *1800*
- *1861*
- *1900*
- *1925*
- *1945*
- *1971*
- *2017*

industrial building by engineer Mattè-Crucco. The next spans of Bertini street building were realized starting from 1919. (ASCT, Pratica Edilizia n°0098, 1919).

In 1920 Porcheddu designed the model makers laboratories portion of "Carlo Garrone" Foundry, a three story building within Savonarola street and Marsiglia avenue. The two story office building and single story structures were soon attached to the former, resulting in the closure of Bertini street (figure 14). The row of buildings on Marsiglia avenue was completed by the two story building for staff, containing cloakrooms, laundries, and dining rooms, realized later in the same year. (ASCT, PE1920_0233_TAV_01).

In 1923 the complex was expanded with an additional floor on managers accommodations (ASCT, Pratica Edilizia n°0747, 1923) and the final

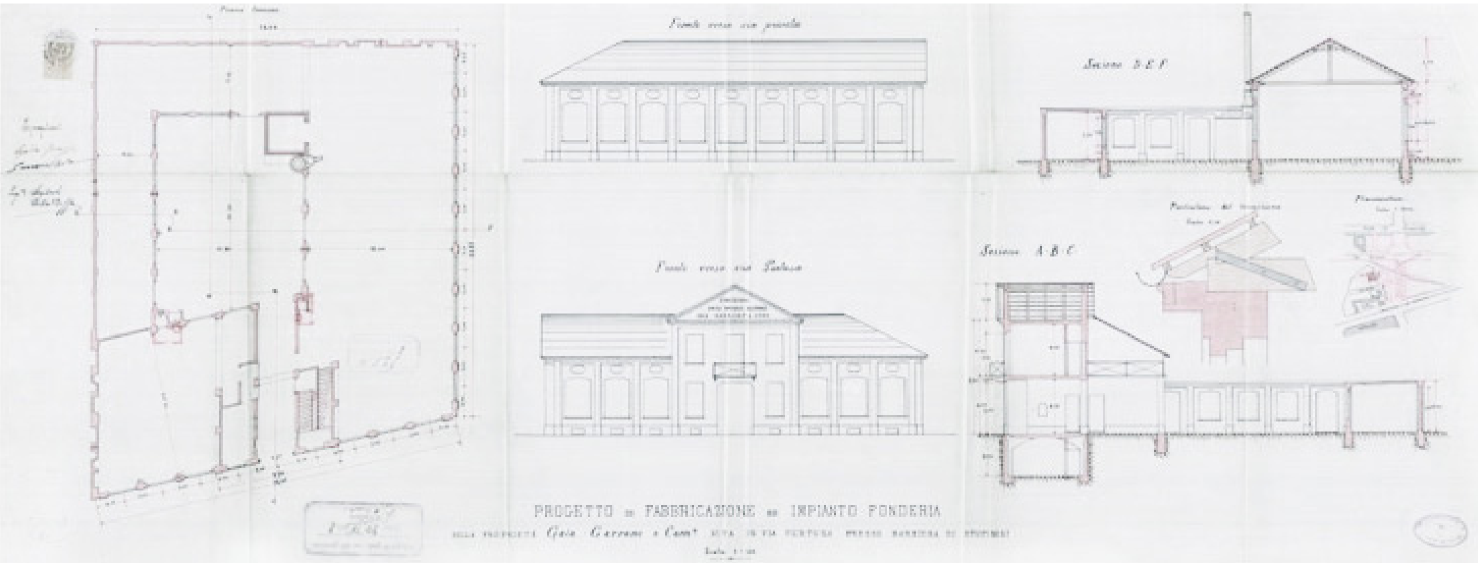
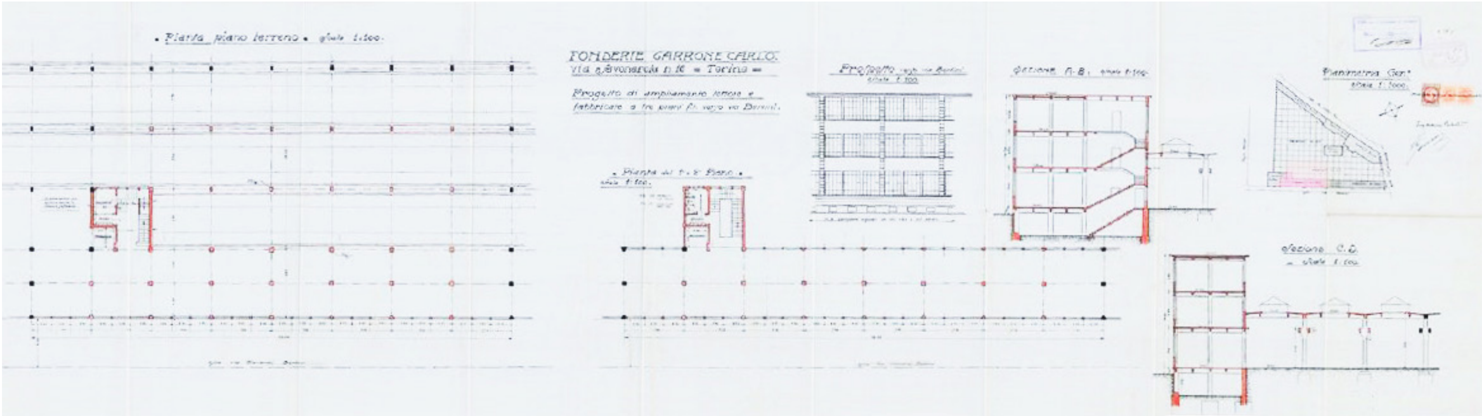


FIGURE 8:
Foundry plant factory project
Source: Historical archive of the city of Turin, PE1908_0125

FIGURE 9:
Carlo Garrone foundry.
Source: Archivio storico della città di Torino, PE1923_0707



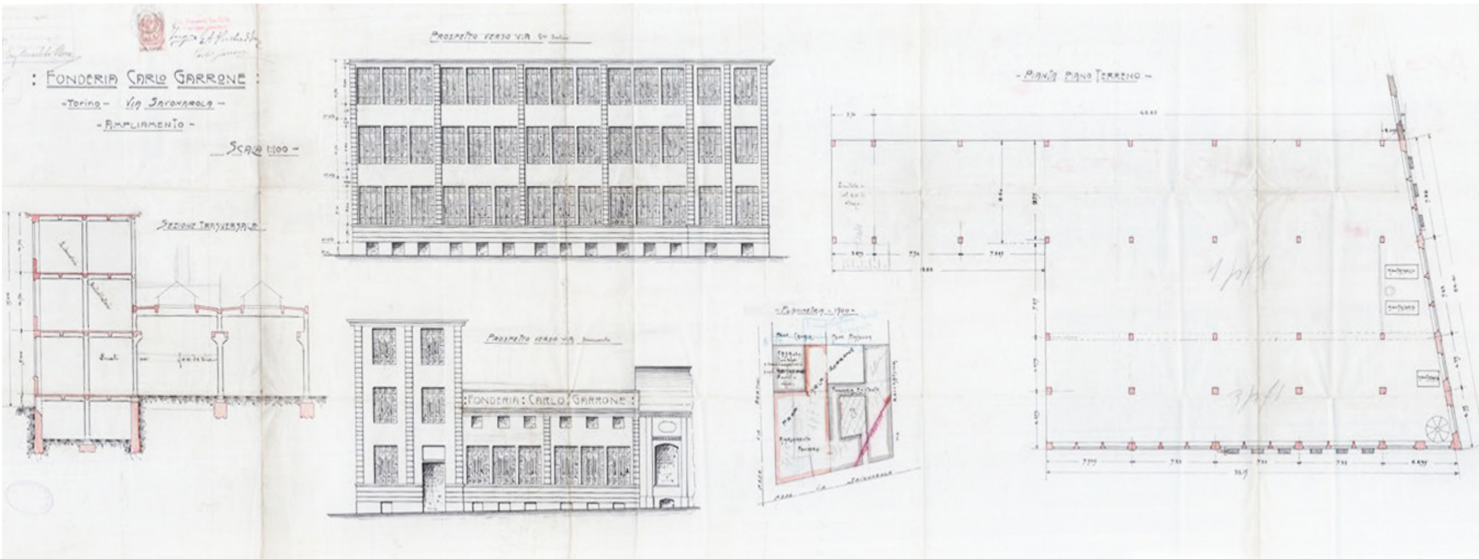


FIGURE 10:
Carlo Garrone foundry.
Source: Archivio storico della città di Torino, PE1915_0397

span of three story buildings on Bertini street (figure 9). The residential building facing Dante avenue and the Miroglio Brothers two story factory building on Montefeltro street were built later in the 1930s.

The impending World War II distracted the focus of the foundries on production of bullets and arms, while the company was renamed as “Società Anonima Trafilati”, expanding its property from the eastern side to the area between Bertini street, Dante avenue Turin-Milan railroad (Osi-East) and building a reinforced concrete industrial structure with shed roof. (AECT, Protocollo 1936_1_10179_dt_01). Other expansions in this period are a portion of brick building for cloakrooms and storage, as well as the vaulted aisle adjacent to Osi-East from the railway side.

The area and nearby surroundings were bombed during the war (figure 11), resulting in various levels of damages (figure 12). The elevation facing Dante avenue and the Osi-east storage, for instance, were among the damaged parts which were restored between 1945-1950, while the ruins of the single story building facing Dante avenue was re-

FIGURE 11:
Map of bombs and incendiary vehicles launched during the II World War,1942-1945. Zone 2: Borgo San Salvario, Parco del Valentino, Vecchia Barriera di Nizza, Borgo San Secondo, Crocetta.
Source: Historical archive of the city of Turin, cart. 68, fasc. 1 disegno 2.

LEGEND

Exploded disruptive bombs
Unexploded disruptive bombs
Fires

FIGURE 12:
Map of the damaged buildings during the II World War, 1942-1945. Zone 2: Borgo San Salvario, Parco del Valentino, Vecchia Barriera di Nizza, Borgo San Secondo, Crocetta.
Source: Historical archive of the city of Turin, cart. 68, fasc. 2 disegno 2.

LEGEND

Very serious damage
Serious damage
Light damage

FIGURE 13:
Expansion of Osi- West area in 1947.
Source: Archivio edlizio della città di Torino, PE1947_1_110017_dt_01

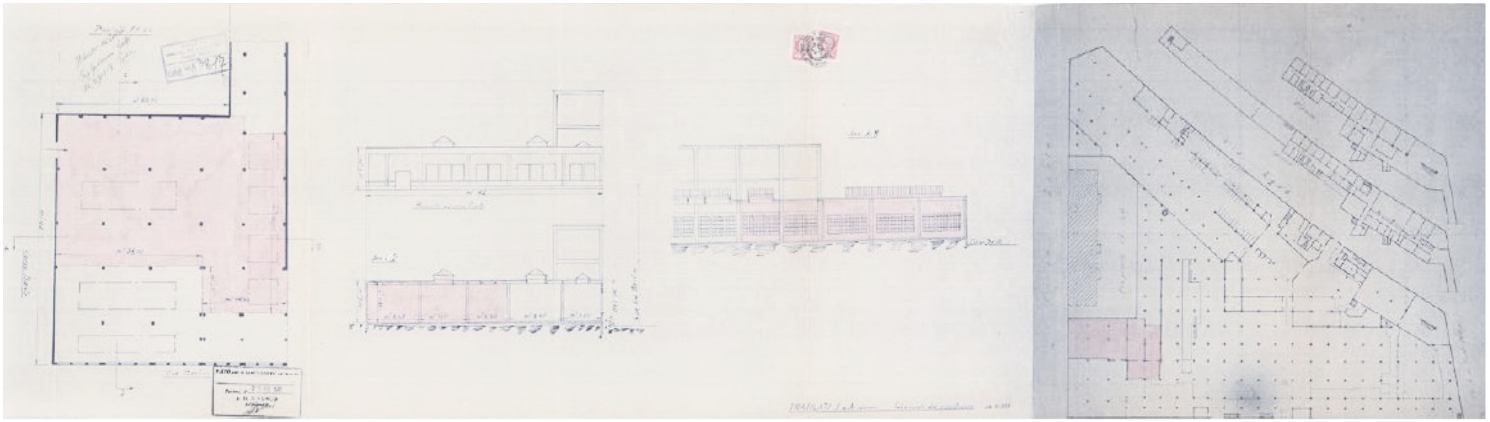


FIGURE 14:
Carlo Garrone foundry.
Source: Archivio storico della città di Torino, PE1920_0195

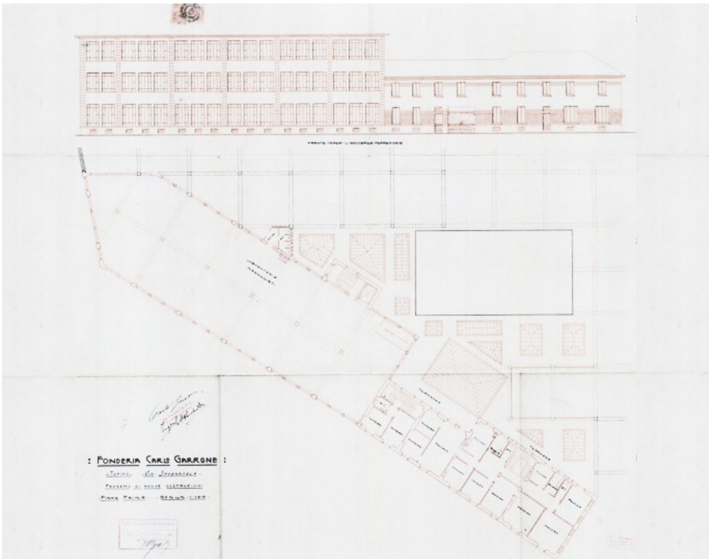
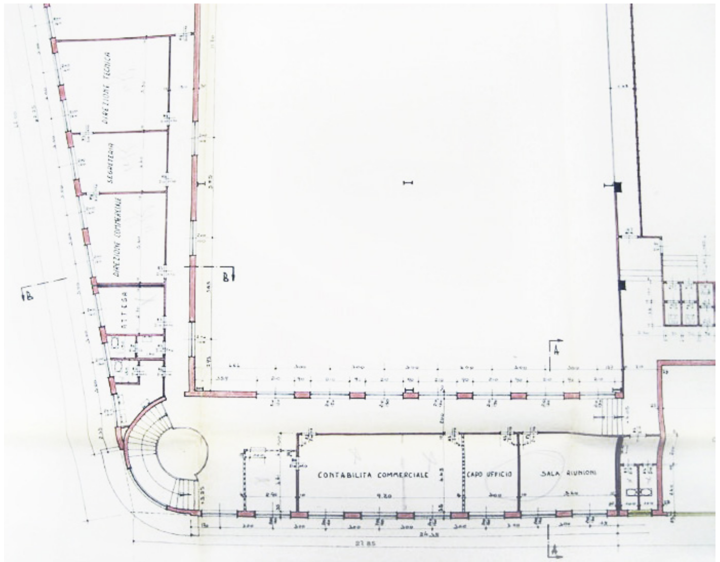


FIGURE 15:
1961 O.S.I building, by architect Diulgheroff.
Source: Archivio edilizio della città di Torino, PE1961_1_60017



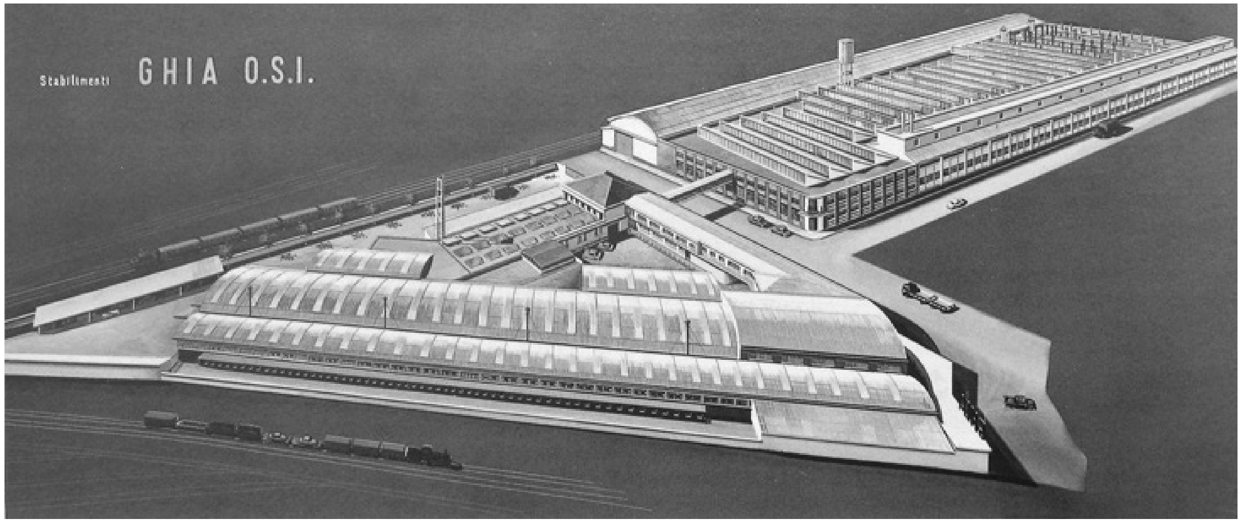
built and expanded in 1947(figure 13). In the post-war years the Italian car industry condition changed and flourished. “Carrozzeria Ghia”, automotive company originally founded in 1916 in Turin by Giacinto Ghia and the Gariglio family as “Carrozzeria Ghia & Gariglio”, at this time was looking for larger production plants, transferring its headquarters first in 1954 to Corso Unione Sovietica 75, then in 1958, to via Agostino da Montefeltro 5, where architect Nicola Diulgheroff designed the new headquarters, consisting of 2 story vaulted roof volumes, attached to a couple of single story buildings repeating the same constructive system. These included offices, conference halls, and design laboratories (figure 16). The Central part was occupied with low rise structures of production and assembly spaces, which were demolished during the remediation process in 2000s. A short time later, Ghia presented the possibility of extending its production, willing to obtain the empty ammunition factory, located on the opposite side of via Agostino da Montefeltro. Following a collaboration agreement Fergat/Olivetti provides the financial means and in 1961,

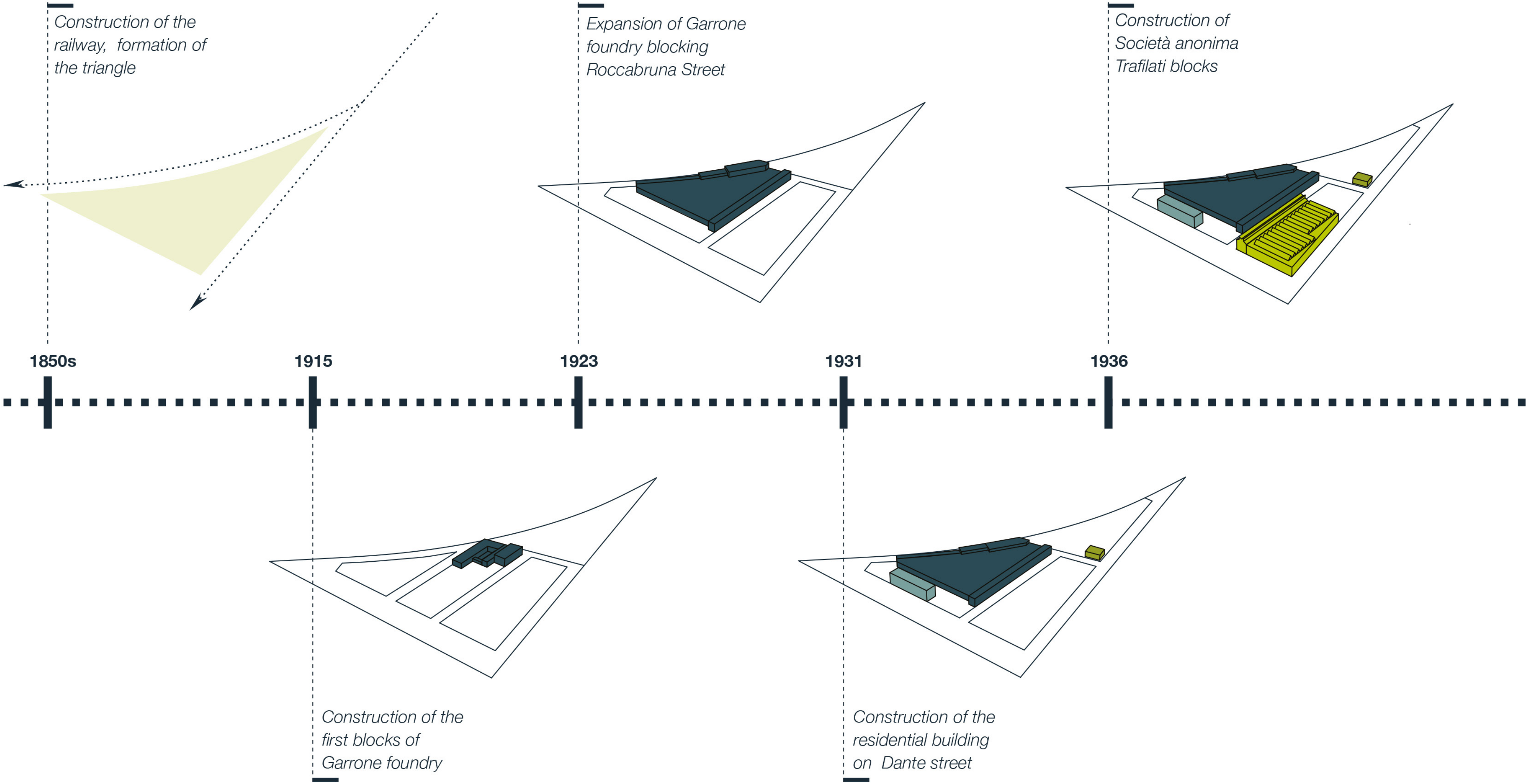
FIGURE 16:
Internal view of Ghia
Source: https://osicar.de/it-ghia-osi.html

FIGURE 17:
Officine Stampaggi Industriali, Innocenti 950 Spyder and Fiat 2300 Coupé, early 1960s
Source: https://osicar.de/it-ghia-osi.html

FIGURE 18:
Aerial view of the Ghia OSI site before the renovation.
Source: https://osicar.de/it-ghia-osi.html

FIGURE 19:
Sketch of the GHIA-OSI industrial area in via Agostino da Montefeltro. The buildings that form a triangle belong to the Ghia, the sheds to the right of the road are the buildings of the OSI.
Source: https://osicar.de/it-ghia-osi.html




Construction of the railway, formation of the triangle
Expansion of Garrone foundry blocking Roccabruna Street
Construction of Società anonima Trafilati blocks
1850s
1915
1923
1931
1936
Construction of the first blocks of Garrone foundry
Construction of the residential building on Dante street

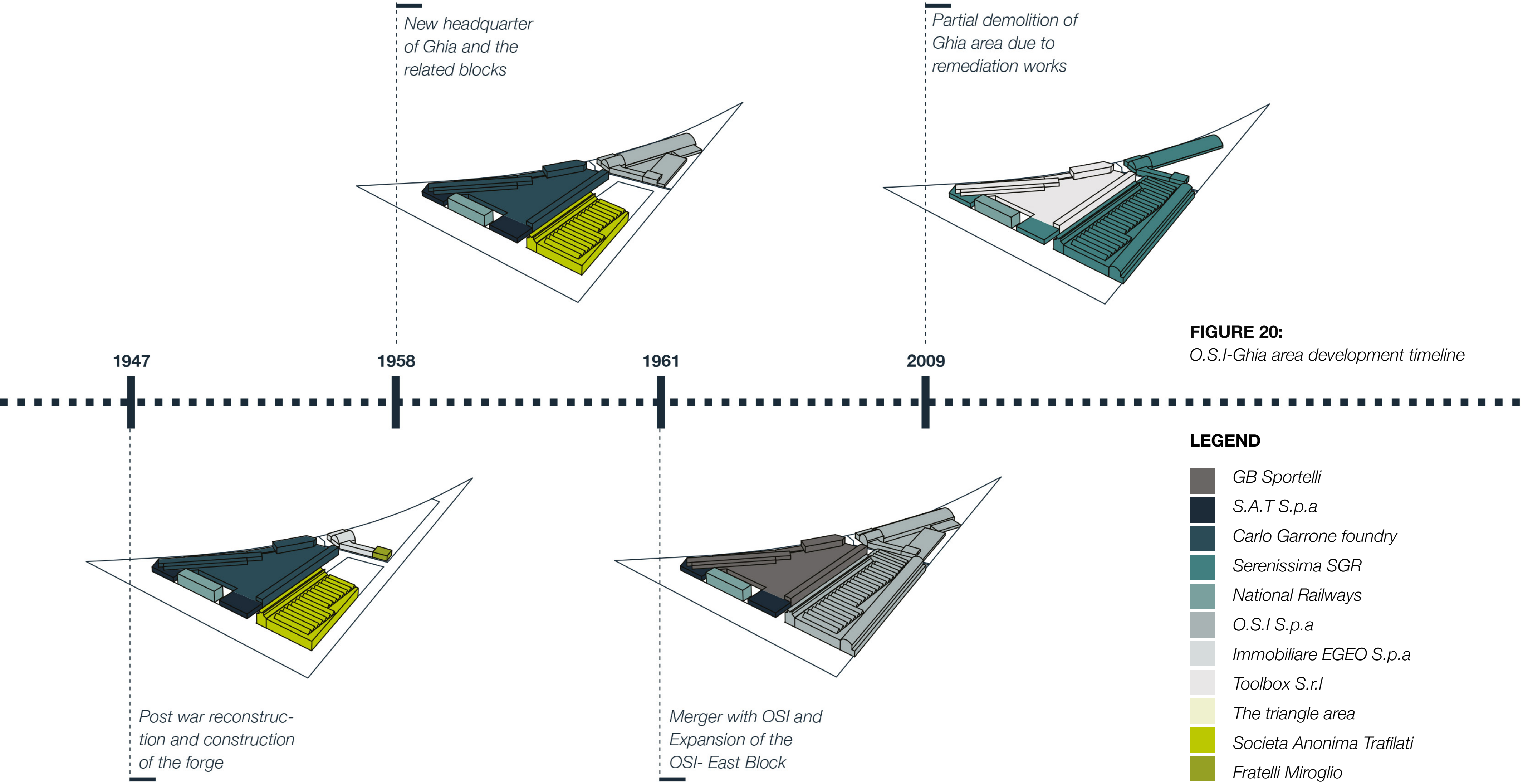


FIGURE 20:
O.S.I-Ghia area development timeline

the "Officine Stampaggi Industriali" (O.S.I), founded by Luigi Segrè and Arrigo Olivetti, purchases the actual Osi-East buildings from "Società Anonima Trafilati", immediately processing the construction of the building between Bertini and Agostino da Montefeltro streets designed by architect Diulgheroff (figure 15). During the Italian economic boom the triangle between the railroads became one of the significant nodes of the car industry developing models for FIAT, Alfa Romeo and Ford (figure 17, figure 18, figure 19). In 1965, 1000 employees were working in three shifts and the daily production of cars amounted to 120 cars, of which 60 pieces belong to the Ford Anglia Torino. In February 1963 Luigi Segre died and the shares of OSI Spa passed completely into the possession of Fergat Spa. However, O.S.I. continued growing, obtaining its own design department in Borgaro district of Turin in 1965 and expanding its area once again with two buildings in 1966. In the meantime the number of employees increased to 2000. However, With the end of the production of the Ford Anglia Torino the daily production and the number of employees fell sharply. Shortly before the end of the millennium, OSI definitively ends its business.

In 1978, architect Aldo Fogli designed the restoration project of the Osi West area for "Società Anonima Trafilati". The project included a new thermal plant according to the contemporary normatives, redesign of internal spaces, redesign of the elevation facing Agostino da Montefeltro street and design of ramps to reach the roof (AECT, PE1978_01_10563). In 1980, the new owner, "Giulio Gianetti Saranno Spa" proceeded with the restoration of the internal spaces of Osi-East (AECT, PE1980_01_10596). The Osi-West area was subjected to restoration works from 1987 to 1989, being redesigned as "Sport City" gym and "Rock City" club, while some portion was acquired by "GB Sportelli" group for their headquarters. The Osi-East area was also sold several times since 1983 to "Società Ruote Spa", then in 1989 to "Findata leasing Spa", in 1998 to "Immobiliare Montefeltro Srl'' and in 2000 to "Delfo Spa". In 2001 Osi-East went back to the possession of the City of Turin, until the acquisition by "Serenissima Sgr" in 2008. Later in the 2000s

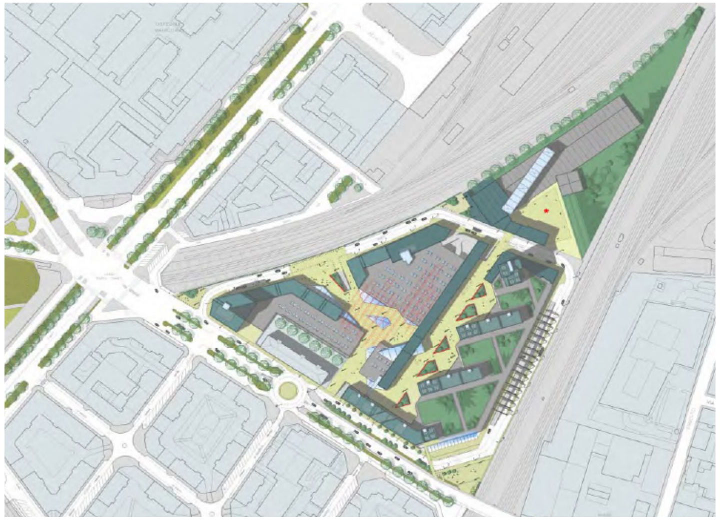


FIGURE 21:
Conventioned Executive Plan by Studio Mellano Associati, 2006.
Source: http://www.servizipubblicaamministrazione.it/venere_storico/cndl823/Data/Allegati/D4-2016-00120-A1.pdf

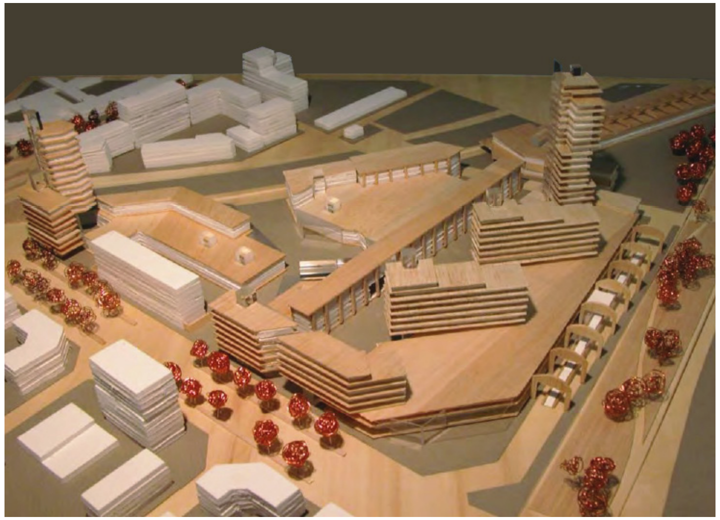


FIGURE 22:
Conventioned Executive Plan by Studio Mellano Associati, 2006.
Source: http://www.servizipubblicaamministrazione.it/venere_storico/cndl823/Data/Allegati/D4-2016-00120-A1.pdf

the area was mostly abandoned, hence becoming a shelter for the homeless and criminal community.
There were then several approaches to introduce a development plan for the area on various scales.
The nr.38 variation of the regulatory plan of Turin in 2006, resulted in the modification of functional distribution in 40 urban transformation zones (Z.U.T.), including the project area, from residential to commercial/production, keeping the 50% the gross floor area.
The draft of an urban transformation project for Serenissima Sgr. was suggested by Mellano studio and Bossolono studio in 2008, according to the 2006 regulatory plan, including some demolition works, redesign of internal roads, large commercial spaces and tall residential buildings. Nonetheless, the economic crisis interfered with the beginning of construction works (figure 21, figure 22).
Another design proposal in the area was developed by a working group of SiTi (Istituto Superiore sui Sistemi Territoriali per l'Innovazione), Municipality of Turin and the national railroad company. Starting from 2000s, the general goal of the group was to

develop strategies for the partial or total recovery of the areas occupied by the railways between Lingotto and Porta Nuova stations, highlighting, in particular the connection of the former OSI-Ghia area to the urban grid, which remains a hypothesis so far.

In 2010, Aurelio Balestra, the new owner of the historical headquarter in Montefeltro street (Osi-West), who obtained it the year before from GB Sportelli, proceeds a restoration project for the internal spaces with architect Caterina Tiazzoldi, developing the American concept of Co-working area (figure 23, figure 24). The initial phase of Toolbox covered 1.000 sqm, with the perspective of covering the whole 10.000 sqm in the future. The toolbox block is however the only active portion in the area.

Paralelly, the Ghia area undergoes an international competition to design the new headquarters of IED. The winning project by Mario Cucinella Architects considered partial reuse of buildings hosting classrooms and laboratories. The 15 storey skyscraper was designated in the corner of the railways containing the student accomodations and related services. A public square was designed

FIGURE 23:
Internal view of Toolbox
Source: https://toolboxcoworking.com/

FIGURE 24:
Internal view of Toolbox
Source: https://toolboxcoworking.com/

FIGURE 25:
IED design by Mario Cucinella Architects
Source: https://www.mcarchitects.it/en/

FIGURE 26:
IED design by Mario Cucinella Architects
Source: https://www.mcarchitects.it/en/

above the covered parking lots in the central area between the skyscraper and the former Ghia building (figure 25, figure 26). Following the competition the remediation process of the central area started by integrating capping technique, but there was no progress later on.

The following variation of the regulatory plan of Turin in 2011, namely: the nr. 234, divided the three areas into the six sub-areas, with no outstanding modification in the urban index (figure 27, figure 28). Fragmentation of the site into sub areas probably meant to ease the development of the distinct portions, but certainly was not enough to stimulate the investors and stakeholders to take evolving steps in this direction. While the abandoned portions of the site have remained unused till now, the local municipal departments of Turin are coming up with various strategies aiming to increase the economic feasibility of the preliminary phase and the profitability of the further development, with a very recent decision about temporary use of abandoned areas, defining certain constraints and flexibility.

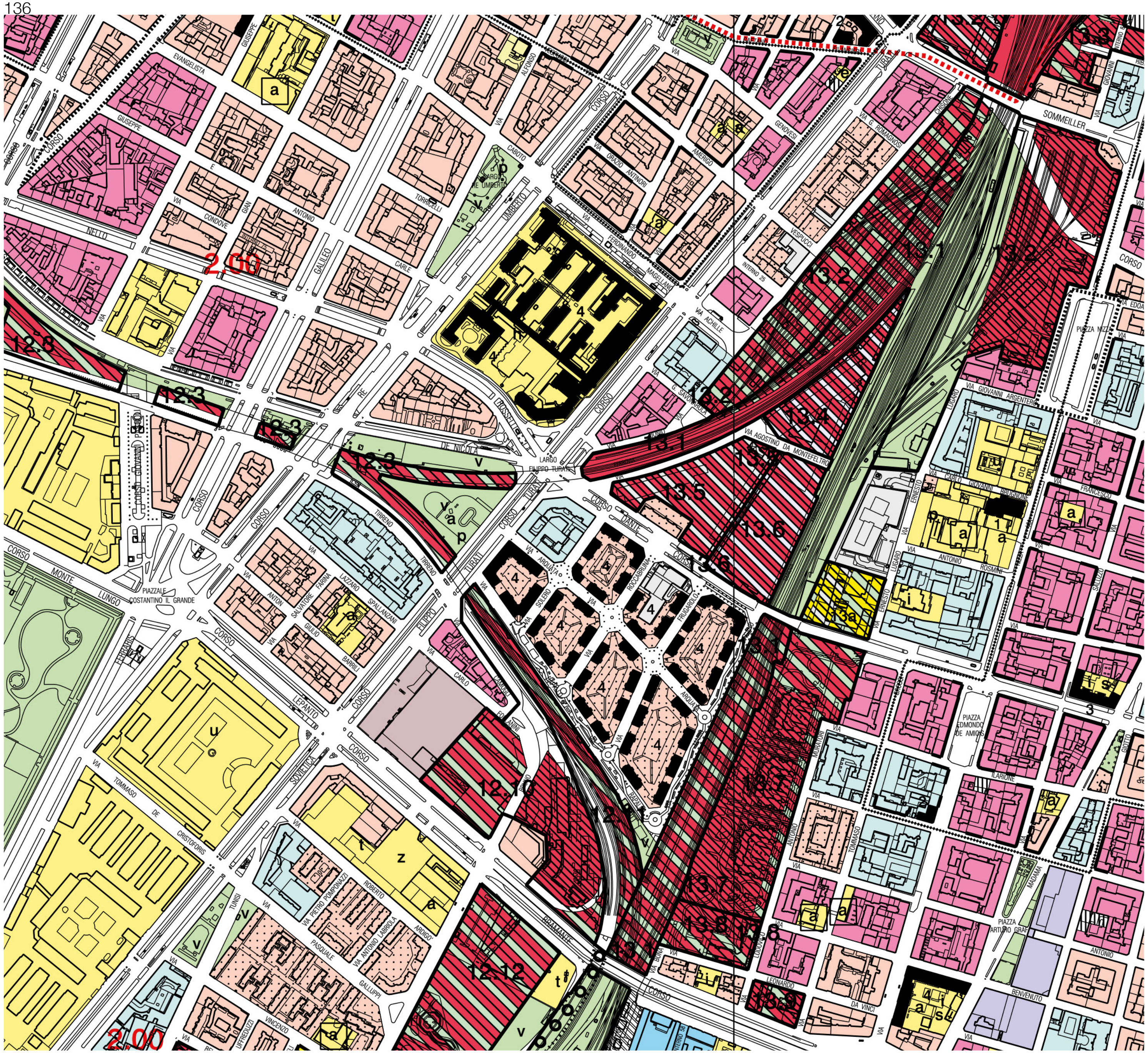
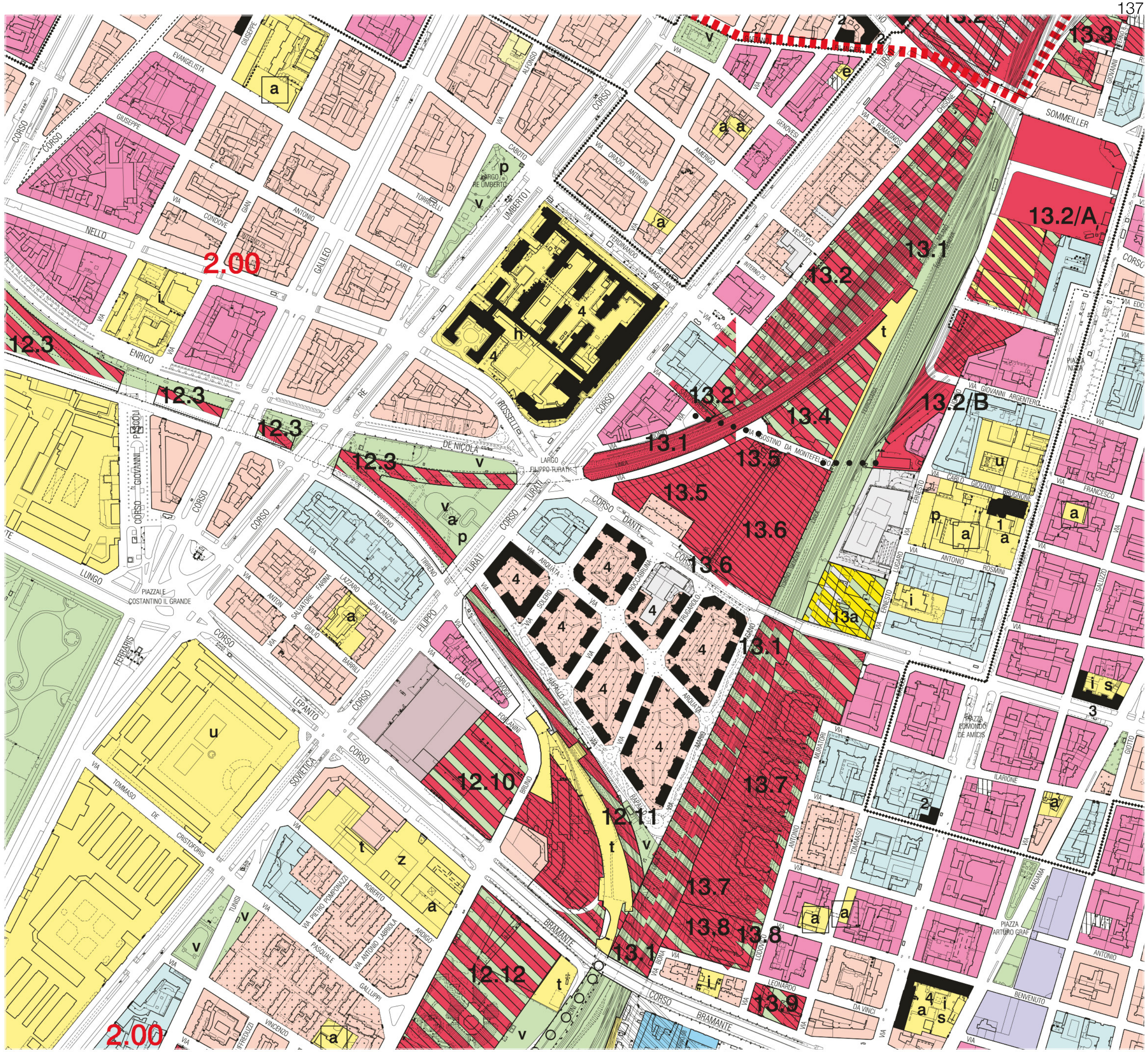


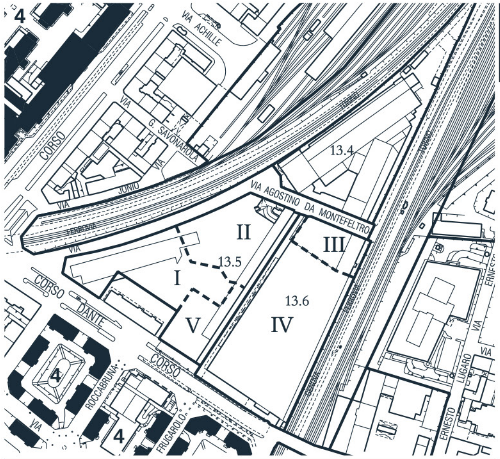
FIGURE 27:
General Plan of Turin (PRG)
Source: Municipality of Turin

LEGEND

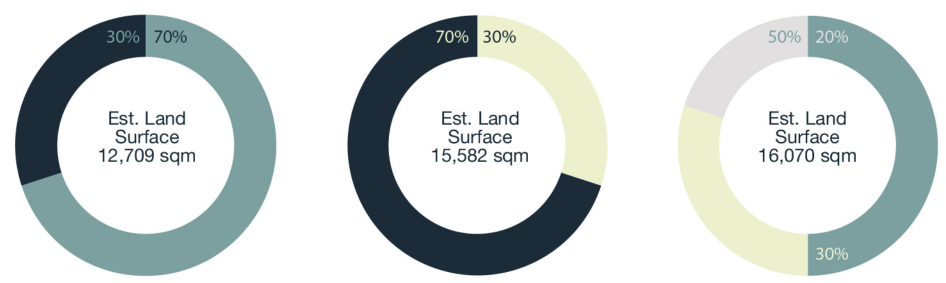
- *Normative Zones*
- *Environmental historic urban areas*
- *Mixed residential consolidated urban areas*
- 2.00 *2,00 mq SLP/mq SF*
- *Private green with pre-existing buildings*
- 1.1 *Urban areas of transformation*
- *Viability*
- *Services*
- *Sport facilities*
- *Continassa - area of redevelopment*
- *Residential*
- *Tertiary activities and service equipment*
- *Residential-Tertiary activities*
- *Productive activity*
- *General interest equipment*
- *Receptive activities*
- *Trade: large-scale distribution*
- *Residential R1*
- *Residential R2*
- *Residential R3*
- *Residential R4*
- *Residential R5*
- *Residential R6*
- *Residential R7*
- *Residential R8*
- *Residential R9*

- Mix M1
- Mix M2
- Area for productive activities IN
- Area for large-scale distribution CO
- Areas for the tertiary sector TE
- i Primary education
- a Equipment for common interest
- v Public park spaces, games and sports
- p Parking lots
- s Higher education
- h Social, health and hospital facilities
- u Universities
- t Technological equipment
- z Other equipment of general interest
- a Private services SP
- 1.a Areas to be transformed for services
- Viability
- Services
- Parks
- Existing roads
- Projected roads
- Projected underground roads
- Areas for railway installations FS
- Buildings of particular historical interest
- Historical relevance
- Divident
- Limit of cemetery respect
- Unified public land project
- Pedestrian routes
- Building wires
- Areas subject to discipline application
- Pedestrian
- Bridge station





	Area 13.4 GHIA	Area 13.5 OSI WEST	Area 13.6 OSI EAST



	Area 13.4 GHIA	Area 13.5 OSI WEST	Area 13.6 OSI EAST
Area 13.4 GHIA	SERVICE		
Sub Area I , Part of 13.5 OSI WEST		Max 7622 sqm / Min 3983 sqm	
Sub Area II , Part of 13.5 OSI WEST		Max 3136 sqm / Min 5764	
Sub Area III , Part of 13.6 OSI EAST			Max 3764 sqm / Min 1800 sqm
Sub Area IV , Part of 13.6 OSI EAST			Max 4494 sqm / Min 3725 sqm
Sub Area V , Part of 13.5 OSI WEST		Max 11000 sqm / Min 6309 sqm	

	Area 13.4 GHIA	Area 13.5 OSI WEST	Area 13.6 OSI EAST
Redevelopment of the Entire Area	●	▲	■
Partial Demolition and Reconstruction	●	▲	■
Functional and Architectural Evaluation	●	▲	■
Environmental Evaluation	●	▲	■
Project consistency with other areas	●	▲	■
Maximum built area = existing SLP	●	▲	■
Up to 35% Hypothesized Residence	●	▲	■
Mitigation required	●	▲	■
Assessment of acoustic impact	●	▲	■

FIGURE 28:
Graphical representation of data from the N° 234 Variant to the PRG of Turin, 2011
Source: Based on data from Municipality of Turin

LEGEND

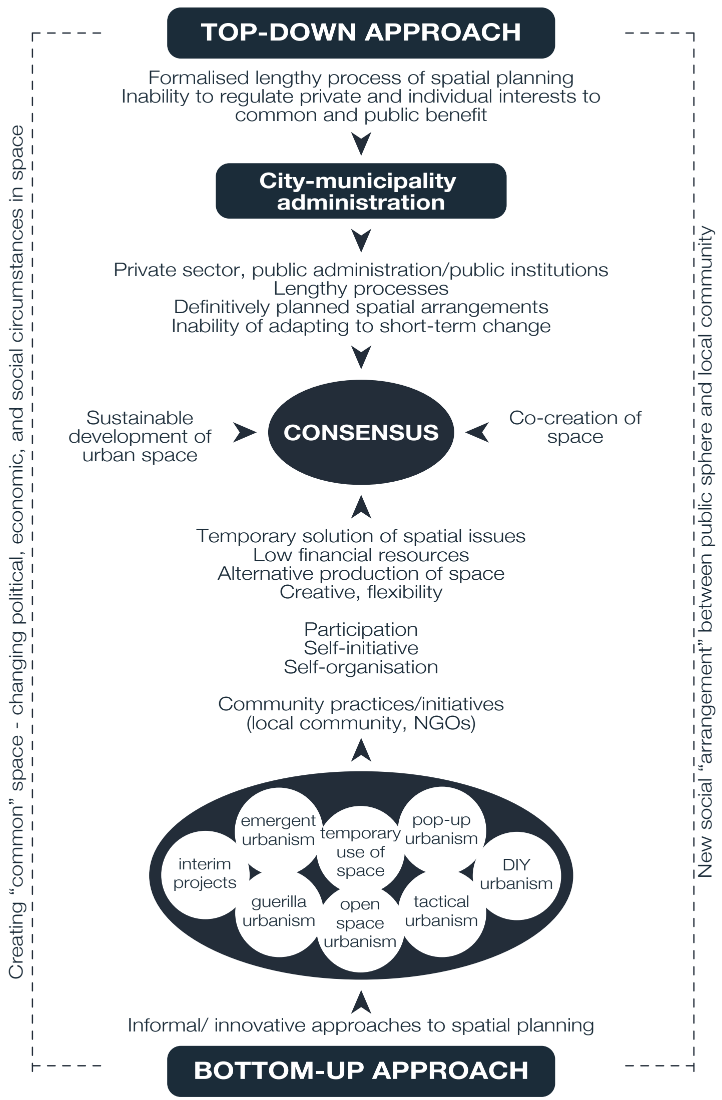
- *Transformation Zone Boundaries*
- IV *Name of the Zone*
- *Service*
- *Productive activities*
- *Commercial activities*
- *Residential*
- *Tertiary activities*

The urban planning and private building department of Turin municipality, in the municipal council of 27 June 2022, discussed the temporary use of the areas pursuant to article 23-QUATER of D.P.R. N. 380/2001 and S.M.I. and of article 8 BIS of L.R. N. 19/199. The legislator established that "temporary use" allowing the utilization of the public and private assets in a state of decay, abandonment or under-used, for carrying out activities or uses subject to alter those permitted by the current PRG, with verification of compliance with the socio-economic requirements and environmental issues related to the public interest. For a more effective management, different methods and criteria are defined according to duration and type of the asset as described below:

1. The temporary use of private areas and/or buildings, provided that they legitimately exist, for a duration of less than 180 days a year, for the implementation of initiatives or activities.
2. The temporary use of legitimately existing private buildings, for a duration of more than 180 days.
3.The admissibility of the temporary use of free areas of private property for a duration more than 180 days will be evaluated in advance by the City Council.

- For all authorized interventions, the Administration is entitled to stabilize the temporary destinations of use, in accordance with current legislation.
- Any urbanization works carried out as part of the temporary intervention, if functional to the subsequent regeneration development of the area, from the costs of urbanization for the same purpose.
- The temporary use of a property, or parts of it, for carrying out activities or uses other than those permitted by the current PRG cannot have a duration of more than five years as a whole.
- The temporary projects must not interfere with the foreseen transformation projects, particularly Urban Transformation Zones(ZUT) or Areas to Transform for Services(ATS), involving the area partially. (Municipal council, 27June 2022)

This decision provides the possibility to experiment with the possible solutions and outcomes for the existing and potential stakeholders for a more realistic analysis and more feasible investment, leaving the field open for further development (figure 29,30,31).



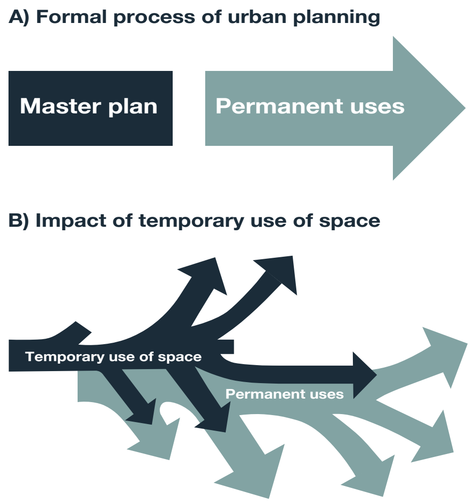
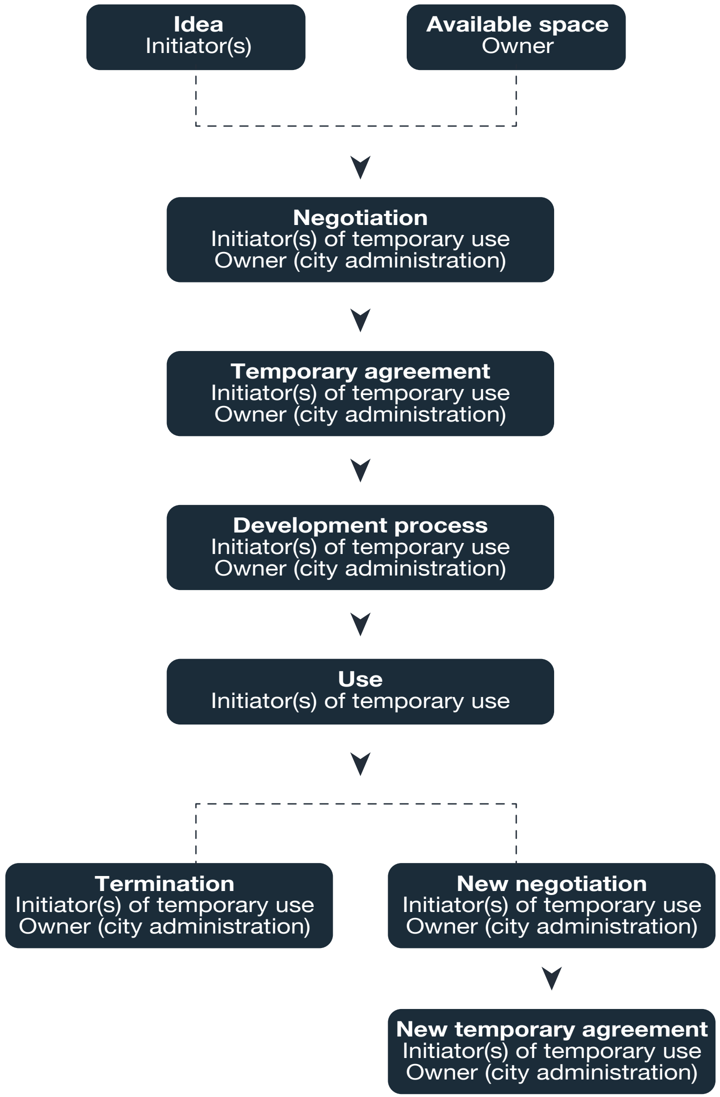


FIGURE 29:
Formal process of the planning in relation to temporary use of space
Source: Cotic, T. and Lah, L.,2016

FIGURE 30:
Alternative developmental model of urban planning by adapting temporary use strategies
Source: Cotic, T. and Lah, L.,2016

FIGURE 31:
Process and participants of temporary use
Source: Reus, T., 2014



Urban-scale Analysis

Being among the abandoned industrial areas of Turin (figure 33) and consequently having a low population density statistics (figure 34), the area is however perfectly connected with the main spots of the city and even better connectivity is projected according to the public transportation development strategies (figure 35, figure 36). The analysis of the built environment horizontal and vertical density (figure 37, figure 38) as well as that of the existing functions (figure 39) and public and private services in the area, mapping of the public and private green spaces, protected built heritage, protected landscape assets (figure 40) and horizontal permeability of the project site (figure 41) provide the necessary basics for the evaluation of the potentials.
Investigating the macroscale and microscale characteristics of the site, the urban scale analysis reveals the peculiarities, connections, boundaries and possibilities, which can be essential and leading for the new development strategies and further analysis and assessments in the project, being environmental, social or economical perspectives.

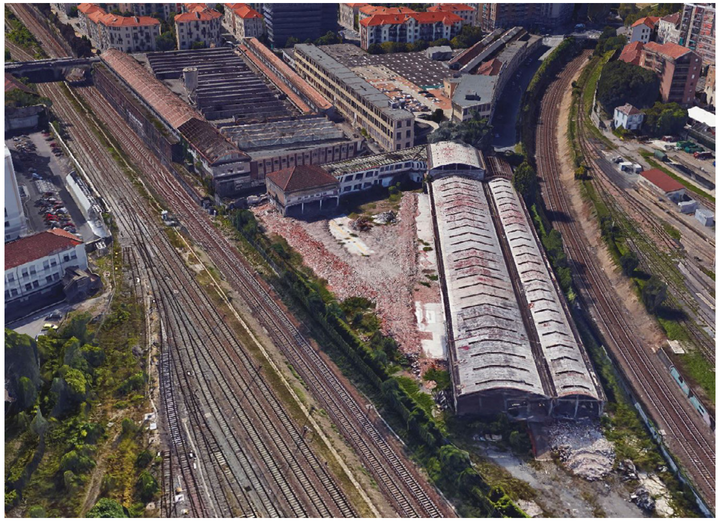


FIGURE 32:
Aerial images of actual situation of the former OSI-GHIA industrial area
Variant to the PRG of Turin, 2011

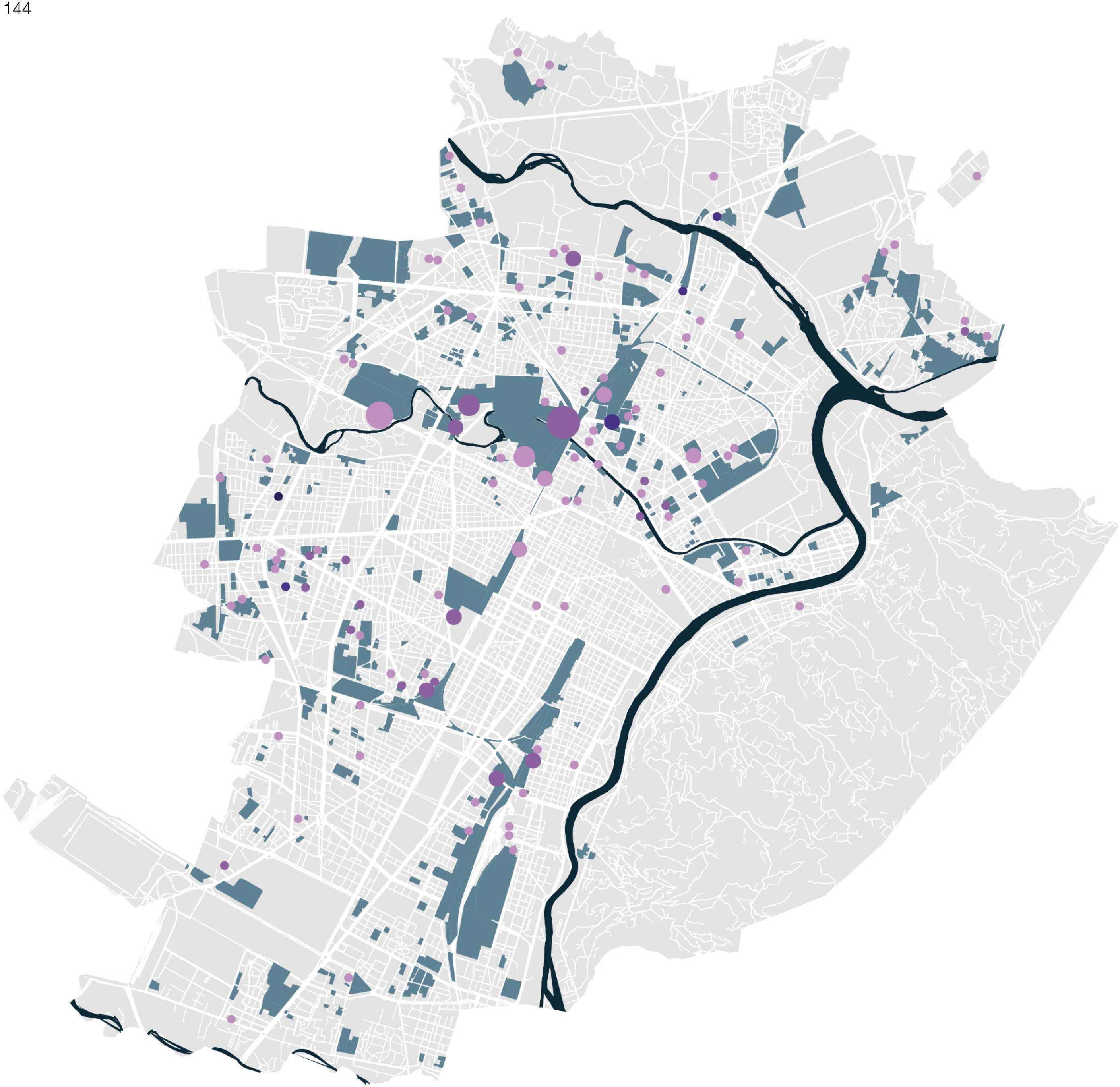


FIGURE 33:
Abandoned Industrial areas of Turin
Source: Torino Atlas 2018

LEGEND

Year of the construction

Area abandoned in 1989,reused before 1997
Area abandoned in 1997,reused before 2001
Area abandoned in 2001,reused before 2005
Area abandoned in 2005,reused before 2012
Area disused in 2012,not yet reused in 2016

Abandoned areas by surface order

Less than 18,000 sq m
Between 18,000 sq m and 60,000 sq m
Between 60,000 sq m and 140,500 sq m
Between 140,500 sq m and 300,000 sq m
Over 300,000 sq m

ZUT - ATS

FIGURE 34:
Population on statistical areas of Turin
Source: Geoportale, Comune di Torino

LEGEND

- N *Statistical zones of Turin*
- *1-5000*
- *5000-10000*
- *10000-15000*
- *15000-20000*
- *> 20000*

FIGURE 35:
Macro Scale: Nearby transportation Systems
Source: Torino Atlas 2018

LEGEND

- *Subway line - Active*
- *Subway line - Future development*
- *Bus line*
- *Subway station - Active*
- *Subway station - Future development*
- *Train station*
- *Train station - Future development*
- *Bike Lanes*
- *Railways*
- *Main access*

FIGURE 36:
Micro Scale: Streets and transportation network
Source: Geoportale, Comune di Torino

LEGEND

- *Local streets*
- *Closed local streets*
- *Main streets*
- *Bike lanes*
- *Railway*
- M *Subway station - Active*
- M *Subway station - Future development*
- T *Train station - Future development*
- N *Nearby bus stops*
- *Bike sharing station*
- *Charging station*

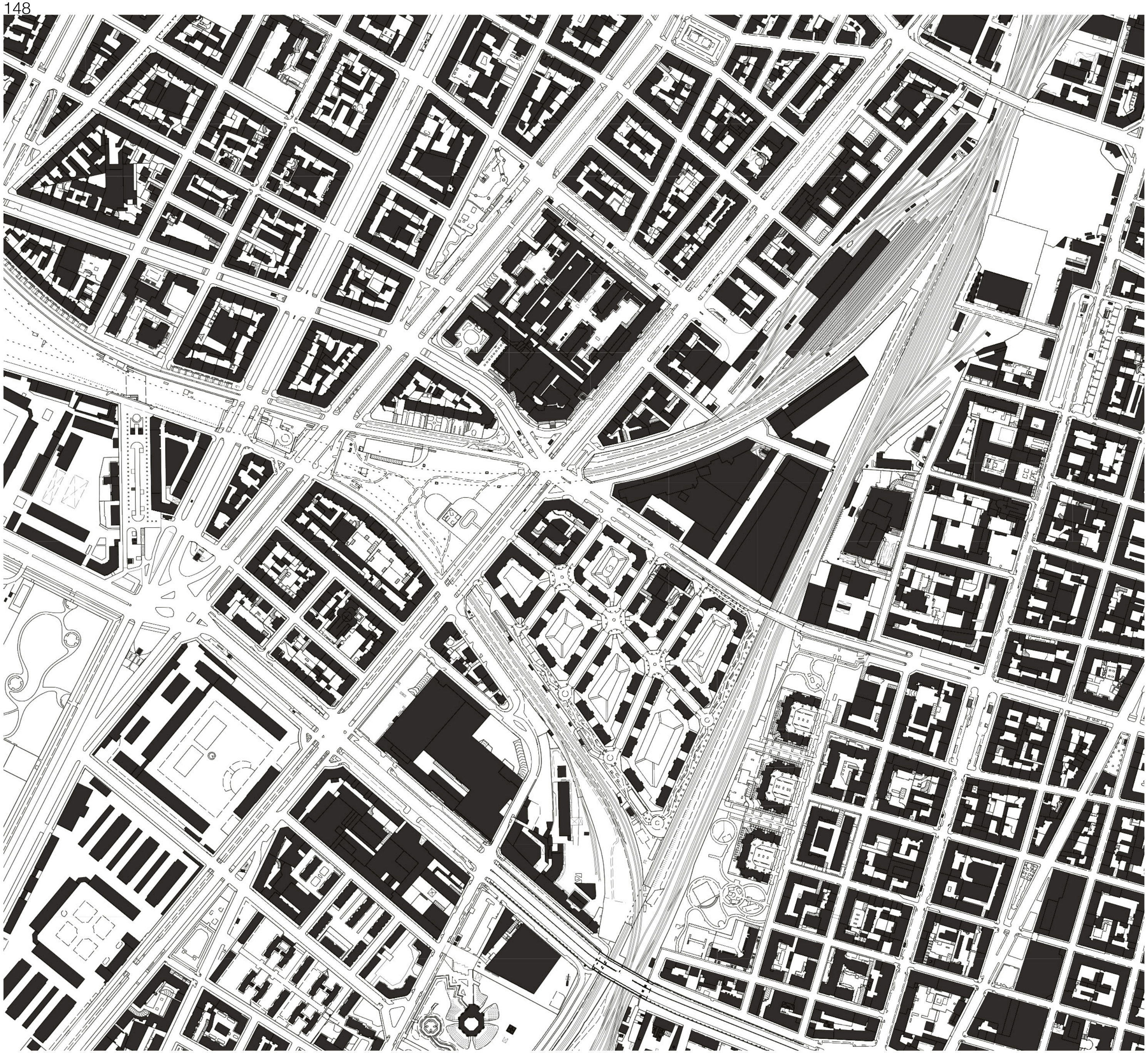


FIGURE 37:
Area density: Fill and void
Source: Geoportale, Comune di Torino

LEGEND

Fill
Void

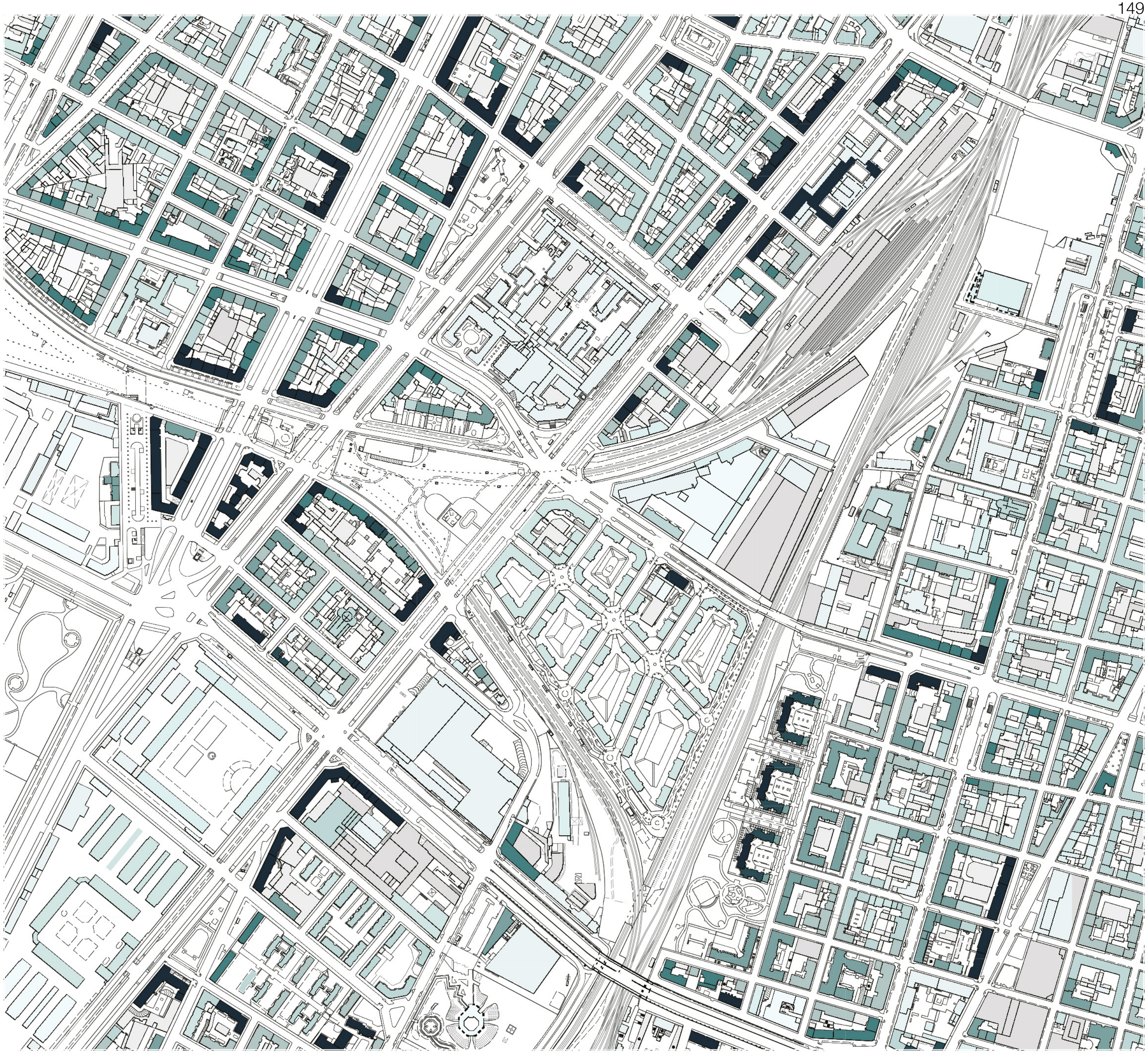


FIGURE 38:
Buildings' height
Source: Geoportale, Comune di Torino

LEGEND

- *1 floor*
- *2 floors*
- *3 floors*
- *4 floors*
- *5 floors*
- *6 floors*
- *7 floors*
- *8 floors*
- *8 floors*
- *10 floors*

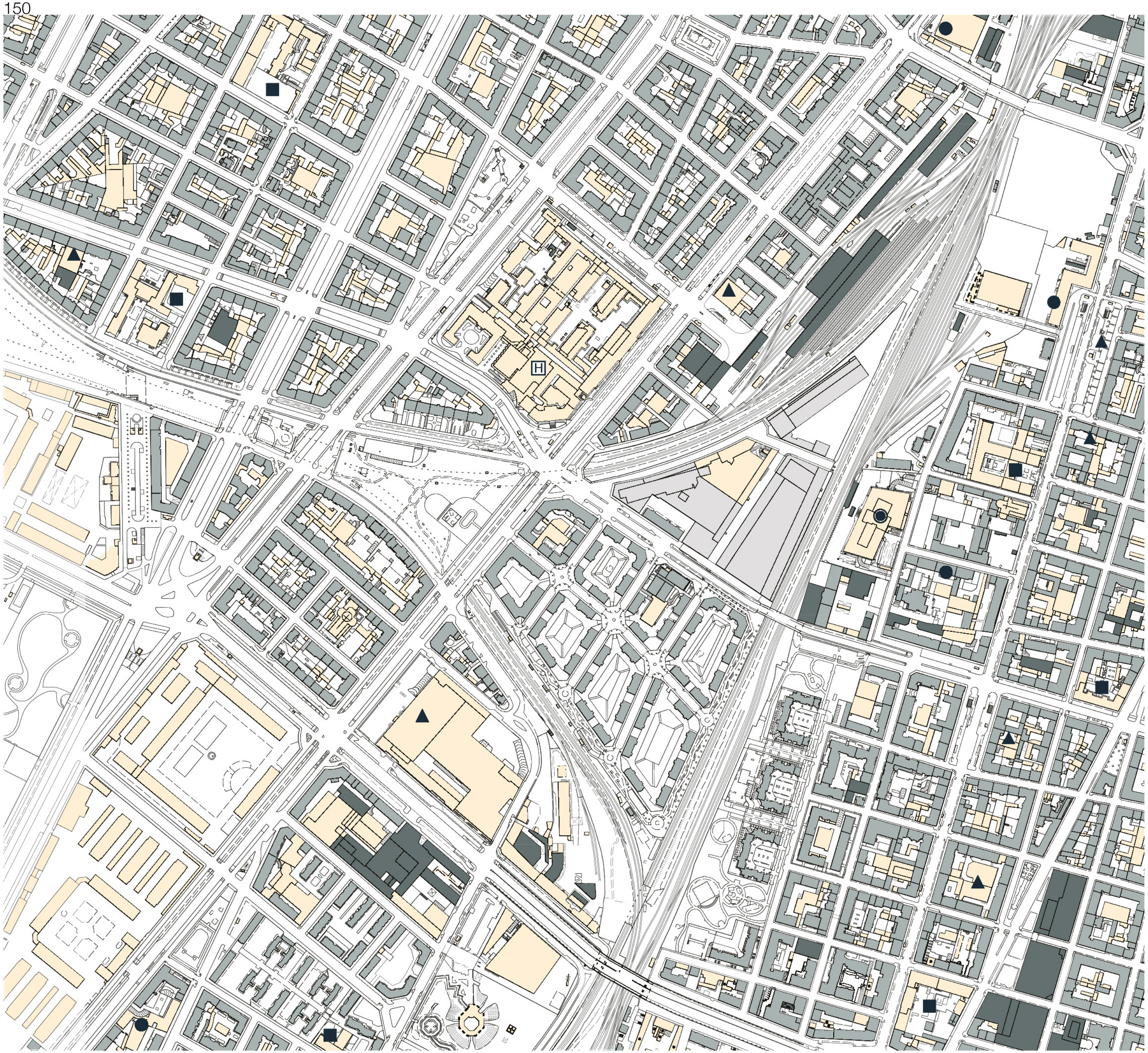


FIGURE 39:
Existing functions
Source: Geoportale, Comune di Torino

LEGEND

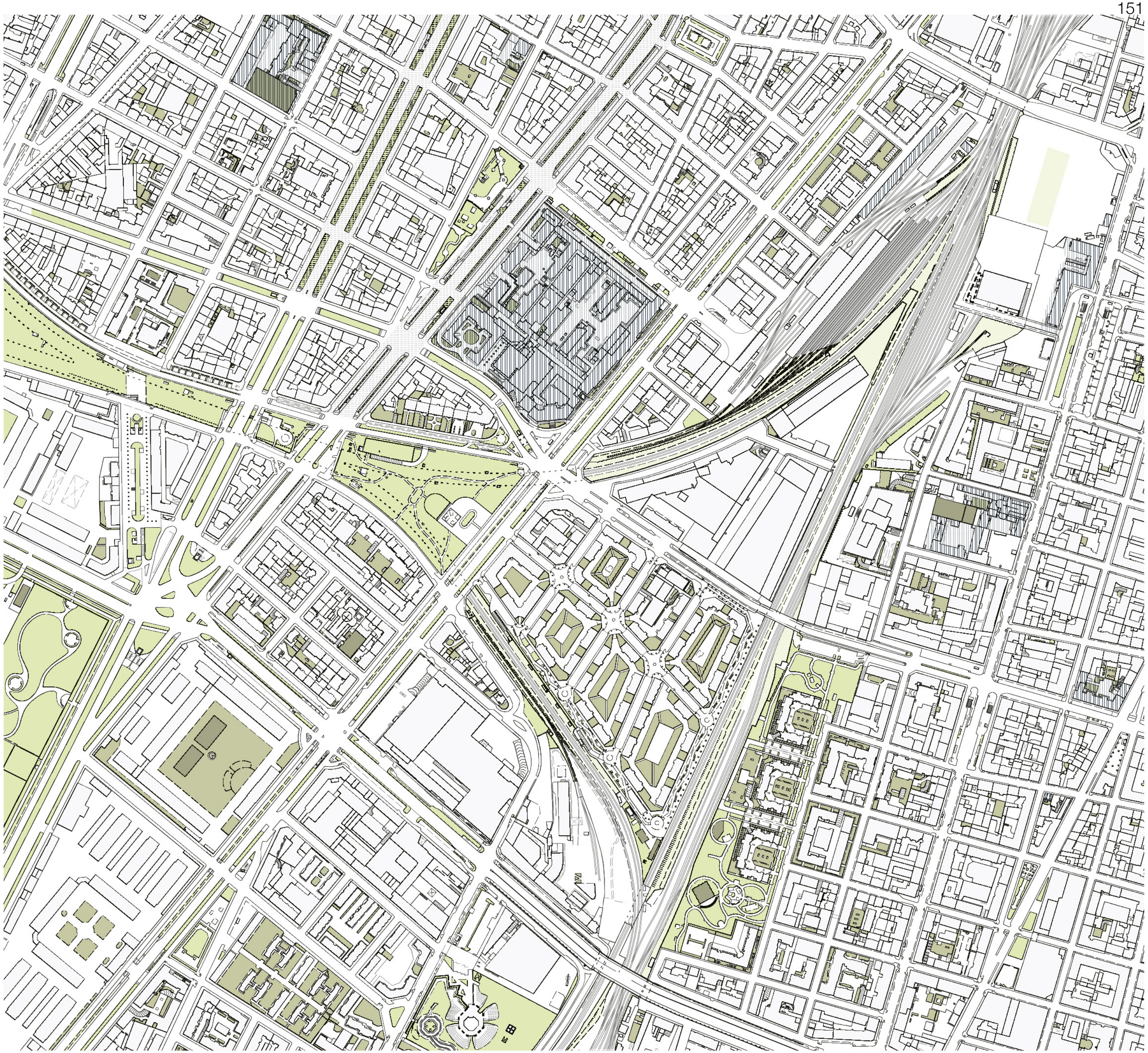


FIGURE 40:
Green area and protected heritage
Source: Geoportale, Comune di Torino

LEGEND

- *Other green*
- *Public green*
- *Private green*
- *Sport green*
- *Protected built heritage*
- *Protected landscape assets*

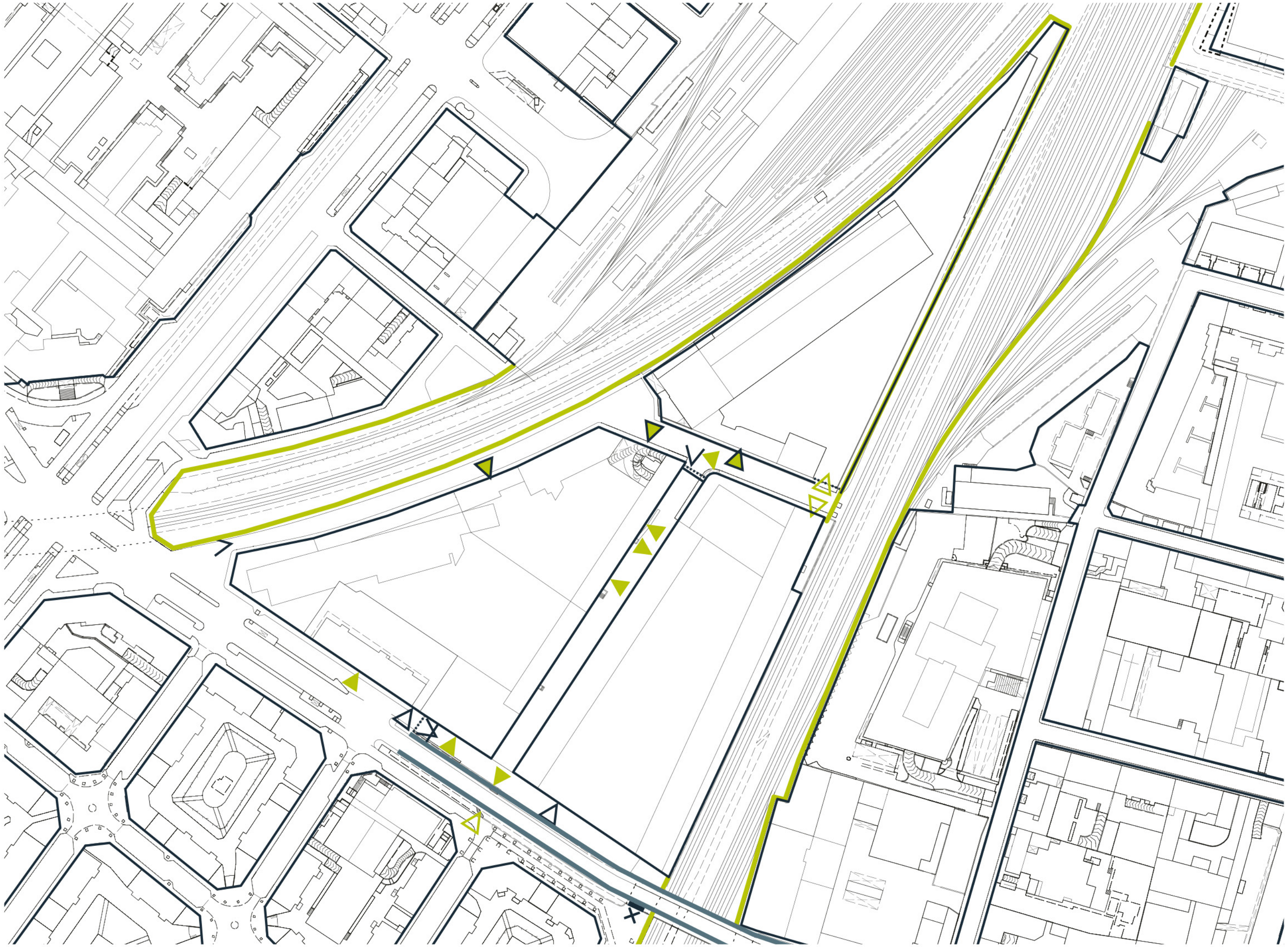


FIGURE 41:
Horizontal permeability map

LEGEND

- *Closed vehicular access*
- *Open vehicular access*
- *Closed pedestrian access*
- *Open pedestrian access*
- *Closed mix access*
- *Public/private limit*
- *Barrier*
- *Overpass*
- *Infrastructure barrier*
- *Pedestrian closed underpass*

Building-scale Analysis

In this section the architectural and structural characteristics of the buildings present in the project area are represented in detail for a better understanding of the volumes and immediate spatial capabilities as well as the internal spaces in order to interpret a more clear image of the potentials of the existing situation.
The drawings and illustrations have been collected and/or reproduced according to the archive data and personal observations.
The drawings include:
- All four levels of existing situation floor plans where buildings structures are present, namely: The roof plan, second floor plan, first floor plan and ground floor plan (figure 42, figure 43, figure 44, figure 45).
- Longitudinal and transversal sections of distinct portions along with thoes of the whole project site.
- Elevations of the streets, presenting an overal image and relative proportions in the area (figure 48, figure 51, figure 53, figure 55). The drawings are accompanied with appropriate images taken on site (figure 46, figure 47, figure 49, figure 50, figure 52, figure 54, figure 56).

Finally, the building scale analysis is concluded with a table representing the data about specific features of each portion of the buildings in the area including information about construction year, the designer, area, number of floors, various uses during the time, state of contamination, the property owner, accessibility and structure type (figure 57).
Based on the data gained in this section a digital three dimentional model of the projects site and existing situation of the present buildings have been created to be used in the next steps of the project development.

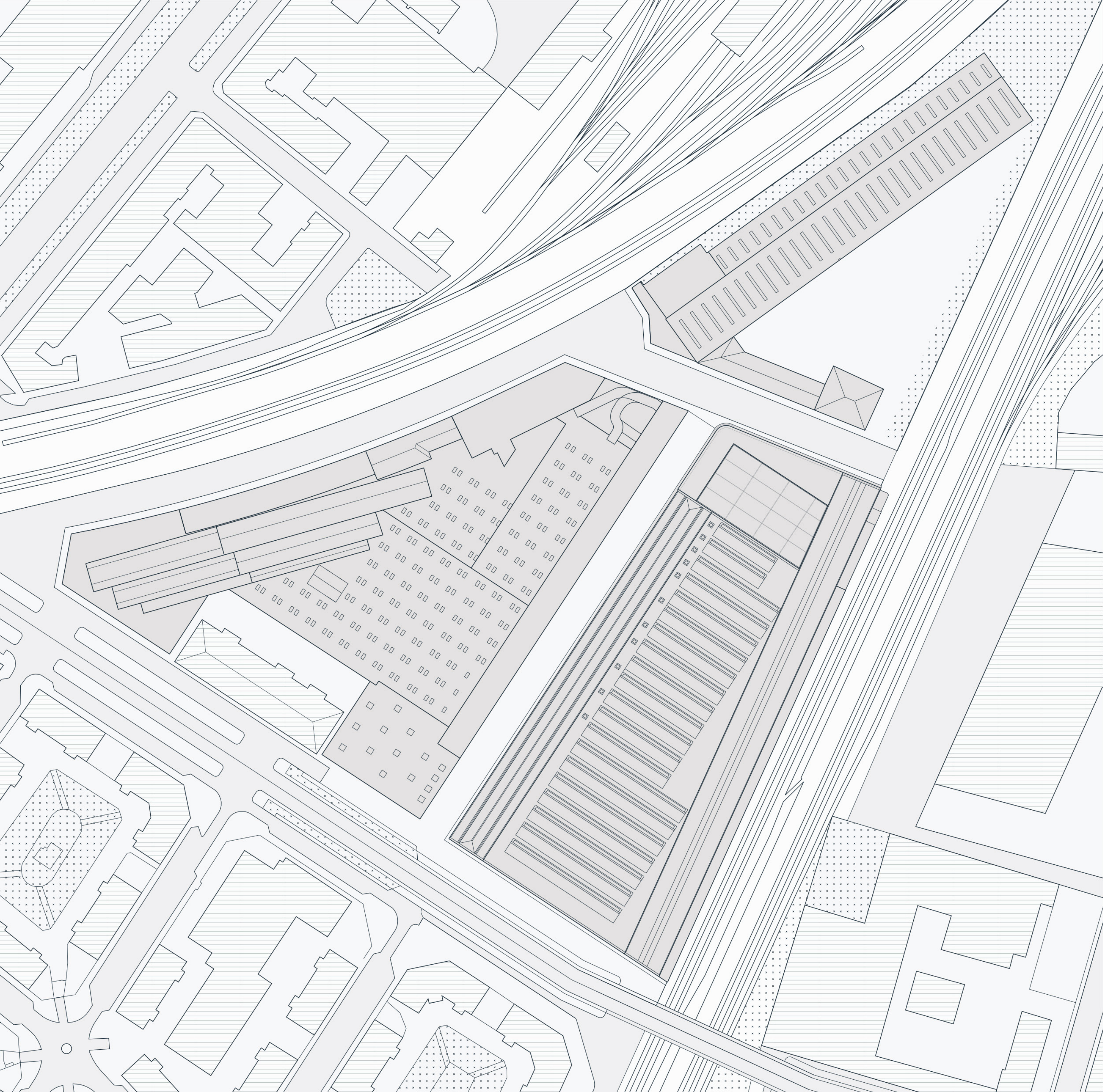
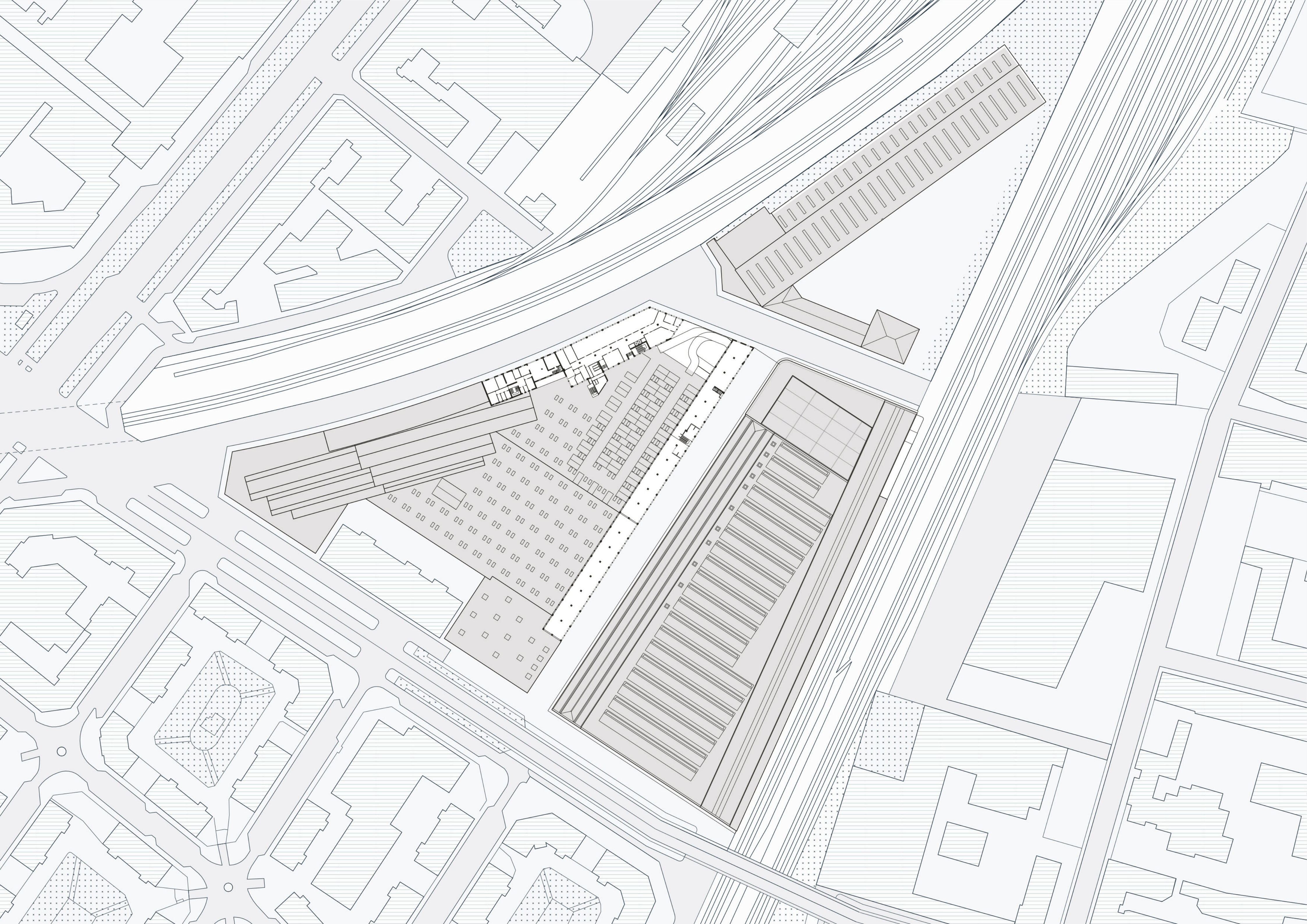


FIGURE 42:
Roof Plan, Existing Situation
Source: Historical archive: PE1920_0195 TAV_01, PE1920_0195 TAV_02 PE1920_0195, PE1923_0747,PE1920_0233 PE1915_0397, PE1919_0098,PE1923_0707 PE1947_1_110017, PE1978_01_10563, PE1987_01_01079, PE1989_01_04033, PE1915_0397, PE1919_0098, PE1923_0707, PE1936_1_10179 Porcheddu Archive: Pratica n°5990, 5989, 5988, 5869, 5937, 5989, 5990, 5937

FIGURE 43:
Second Floor Plan, Existing Situation
Source: Historical archive: PE1920_0195 TAV_01, PE1920_0195 TAV_02 PE1920_0195, PE1923_0747,PE1920_0233 PE1915_0397, PE1919_0098,PE1923_0707 PE1947_1_110017, PE1978_01_10563, PE1987_01_01079, PE1989_01_04033, PE1915_0397, PE1919_0098, PE1923_0707, PE1936_1_10179 Porcheddu Archive: Pratica n°5990, 5989, 5988, 5869, 5937, 5989, 5990, 5937



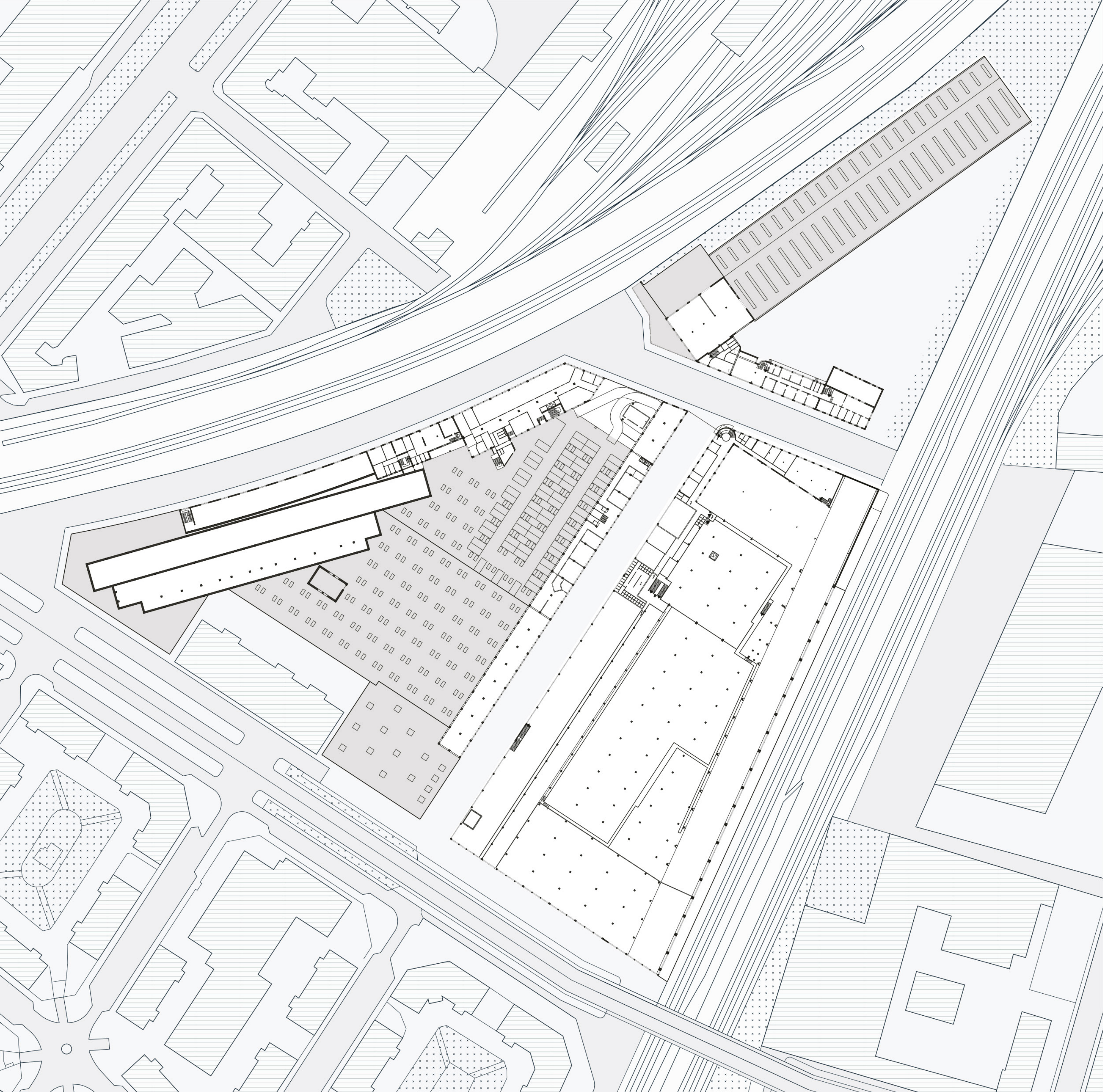


FIGURE 44:
First Floor Plan, Existing Situation
Source: Historical archive: PE1920_0195 TAV_01, PE1920_0195 TAV_02 PE1920_0195, PE1923_0747,PE1920_0233 PE1915_0397, PE1919_0098,PE1923_0707 PE1947_1_110017, PE1978_01_10563, PE1987_01_01079, PE1989_01_04033, PE1915_0397, PE1919_0098, PE1923_0707, PE1936_1_10179 Porcheddu Archive: Pratica n°5990, 5989, 5988, 5869, 5937, 5989, 5990, 5937

FIGURE 45:
Ground Floor Plan, Existing Situation
Source: Historical archive: PE1920_0195 TAV_01, PE1920_0195 TAV_02 PE1920_0195, PE1923_0747,PE1920_0233 PE1915_0397, PE1919_0098,PE1923_0707 PE1947_1_110017, PE1978_01_10563, PE1987_01_01079, PE1989_01_04033, PE1915_0397, PE1919_0098, PE1923_0707, PE1936_1_10179 Porcheddu Archive: Pratica n°5990, 5989, 5988, 5869, 5937, 5989, 5990, 5937

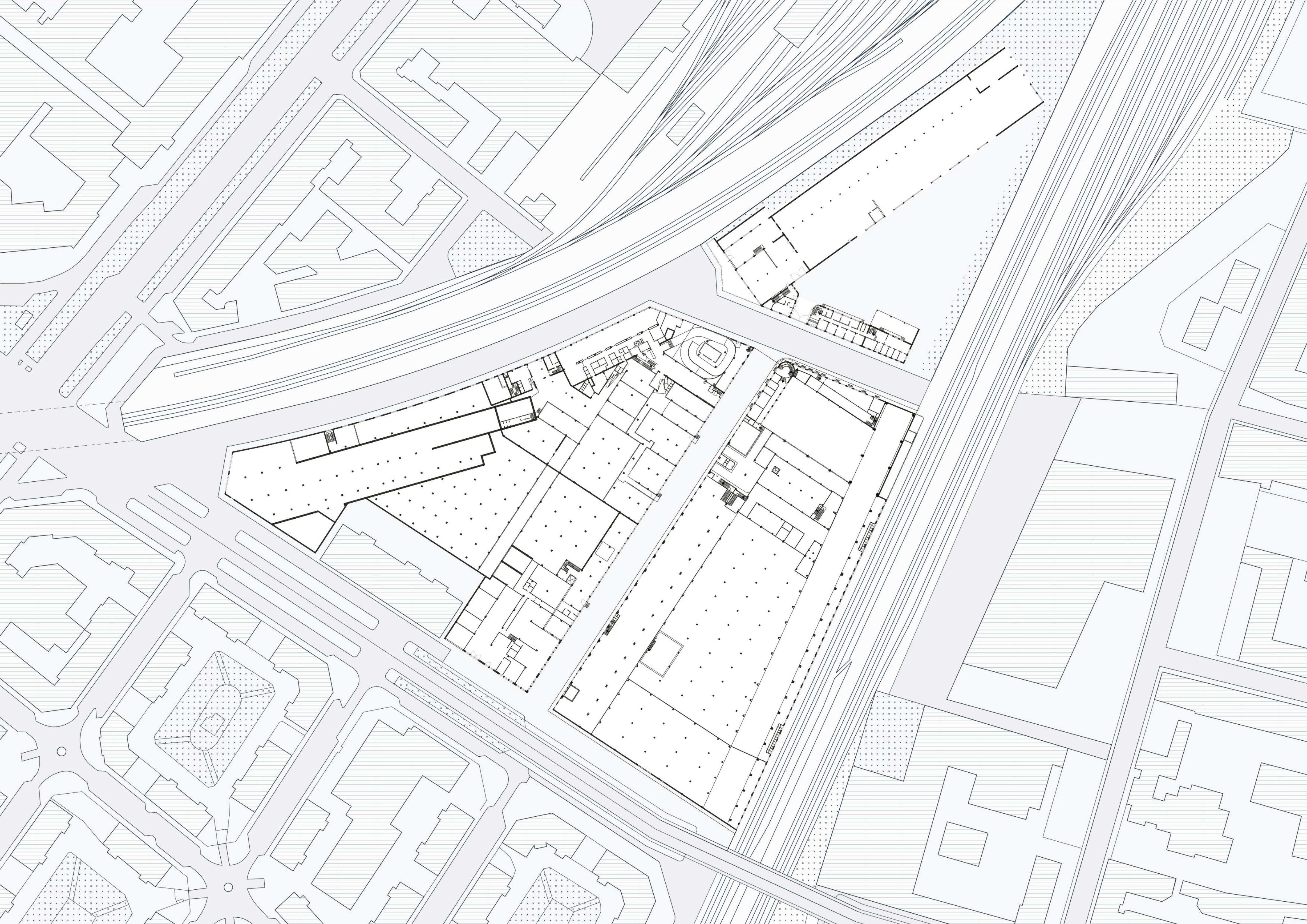
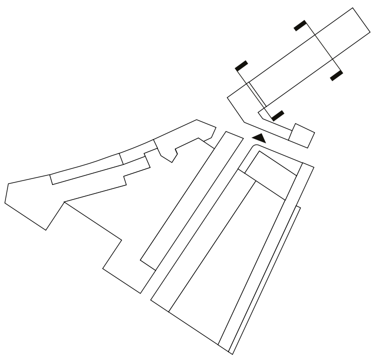


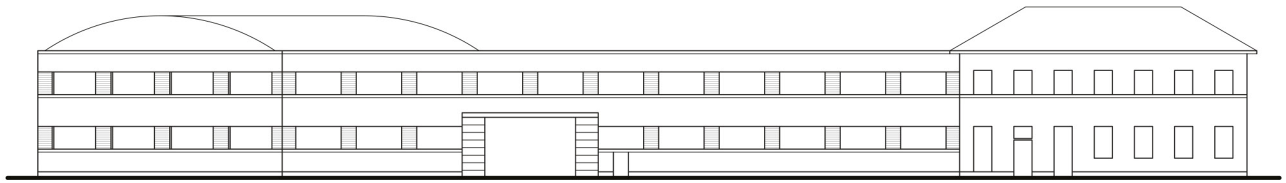
FIGURE 46:
Actual Situation Images of GHIA Area
Source: By authors

FIGURE 47:
Actual Situation Images of GHIA Area
Source: Karaca. M, Merve.K (2021) ,
Iannetti, D., Morini, S. (2019)

FIGURE 48:
Actual Sections and Elevation of GHIA Area
Source: Building's archive
PE1958_1_10493, PE1958_1_10493

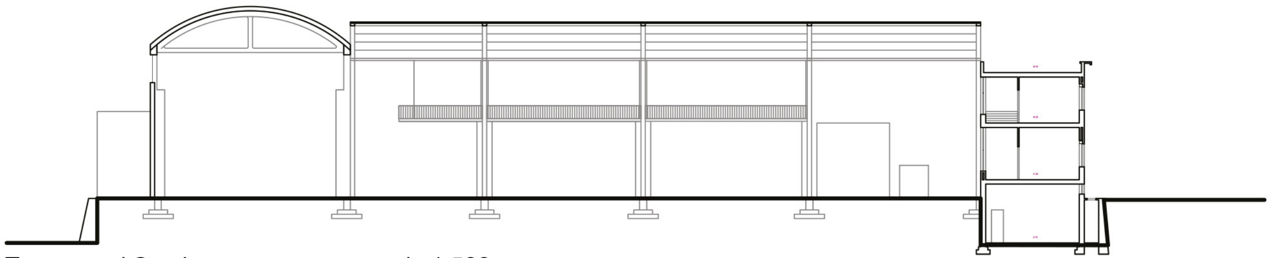


Sections scale 1:500



Via Montefeltro Elevation scale 1:500

FIGURE 49:
Actual Situation Exterior Images of OSI-East Area
Source: By authors



Transversal Section scale 1:500

Via Montefeltro Elevation scale 1:500

FIGURE 50:
Actual Situation Interior Images of OSI-East Area
Source: Karaca. M, Merve.K (2021) , Iannetti, D., Morini, S. (2019)

FIGURE 51:
Actual Sections and Elevation of OSI Area
Source: Building's archive
PE1961_1_60017, PE1980_01_1059

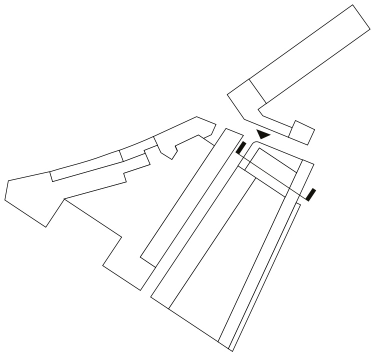
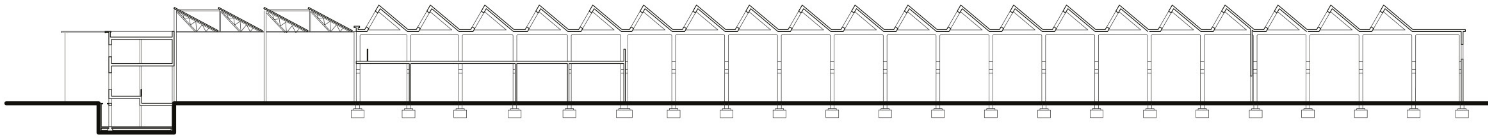
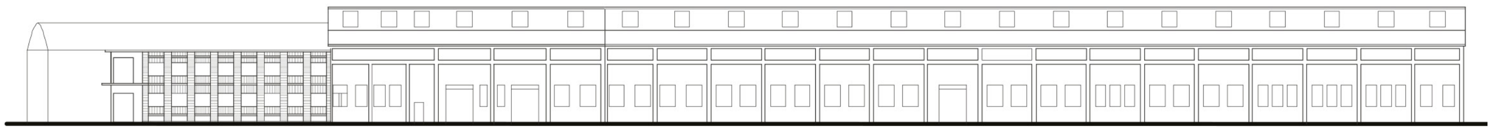



FIGURE 52:
Actual Situation Images of OSI-East Area
Exterior Images Source: By authors
Interior Images Source: Iannetti, D., Morini, S. (2019)

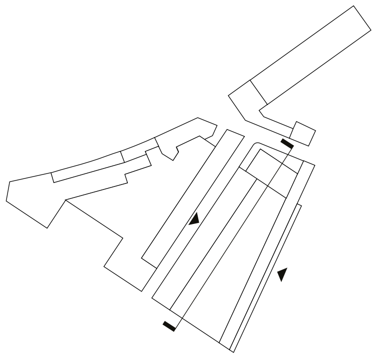


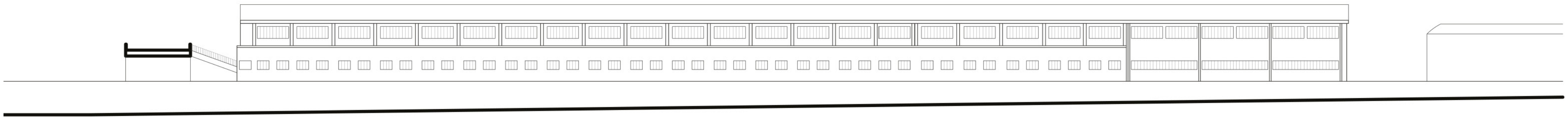
Longitudinal Section scale 1:1000



Via Bertini Elevation scale 1:1000

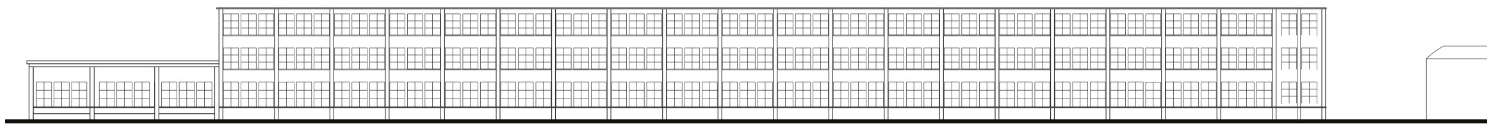
FIGURE 53:
Actual Sections and Elevation of OSI Area
Source: Historical archive:1936_1_10179
Building's archive: 1961_1_60017
1980_01_10596, 1936_1_10179



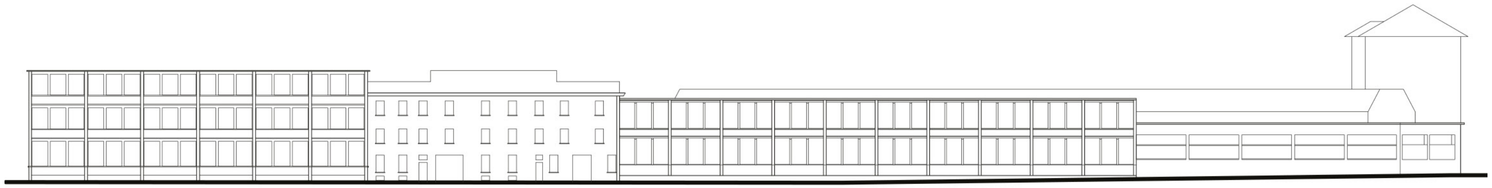


Eastern Elevation scale 1:1000

FIGURE 54:
Actual Situation Images of OSI-West Area
Source: By authors



Via Bertini Elevation scale 1:1000



Via Egeo Elevation scale 1:1000

FIGURE 55:
Actual Sections and Elevation of OSI Area
Source: Historical archive: PE1915_0397, PE1919_0098, PE1923_0707, PE1947_1_110017, PE1978_01_10563, PE1987_01_01079, PE1989_01_04033, PE1920_0233

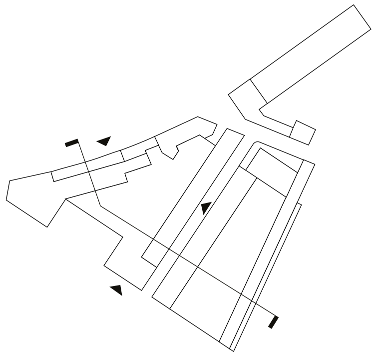
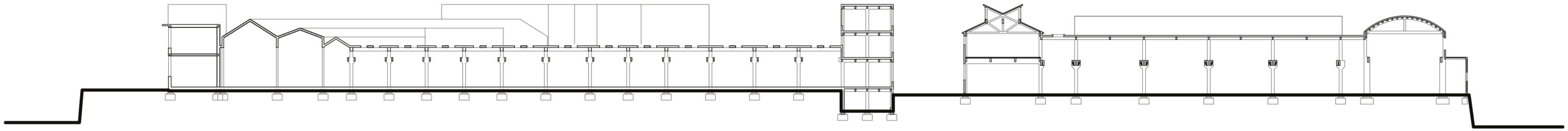
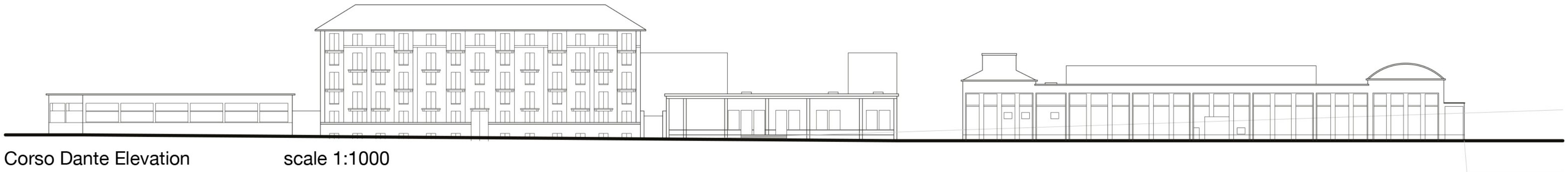


FIGURE 56:
Actual Situation Images of OSI-West Area
Source: By authors

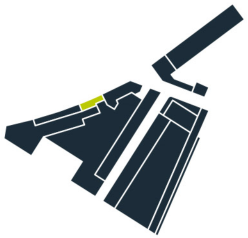
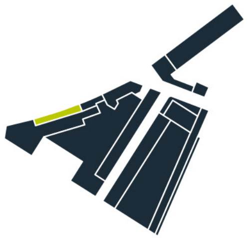


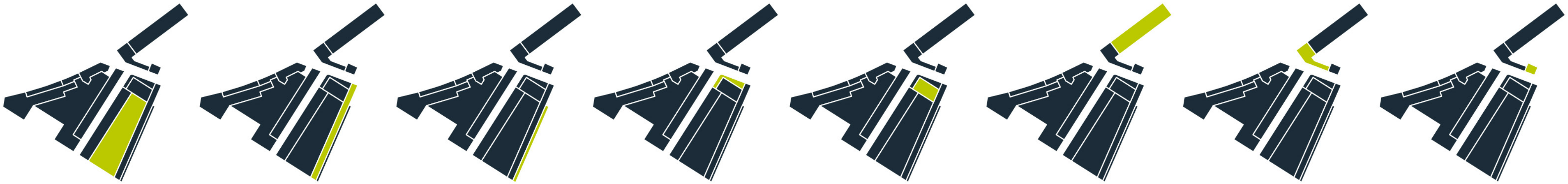
Section scale 1:1000



Corso Dante Elevation scale 1:1000

FIGURE 57:
OSI-Ghia Buildings' Data

	A-I	A-II	A-III	A-IV	A-V	A-VI	B-I
							
Urban Area	Osi West	Osi West	Osi West	Osi West	Osi West	Osi West	Osi East
Construction Year	1920	1920	1920-1923	1920	1915-1923	1915-1923	1940
Designer	Porcheddu	Porcheddu	Porcheddu	Porcheddu	Porcheddu	Porcheddu	Jacazio
Area	817 sqm	322 sqm	600 sqm	2995 sqm	8424 sqm	1290 sqm	1982 sqmññ
N ° Floors	3	3	2	1	1	3	2
Previous Use	Modeling laboratory	Offices	Staff area	Industrial	Steel mill	Office,Warehouse,Club	Powerplant,Warehouse
Remediation	Yes	Yes	No	No	Partially	Partially	No
Current Use	Toolbox	Toolbox, Casa Jasmina	Abandoned	Abandoned	Toolbox	Toolbox	Abandoned
Owner	Toolbox Srl	Toolbox Srl	Europa Risorse SGR	Europa Risorse SGR	Toolbox/Europa Risorse SGR	Toolbox/Europa Risorse SGR	Europa Risorse SGR
Pedestrian access	Via Montefeltro	Via Egeo	Via Egeo	Corso Dante	Dante/Via Montefeltro	Via Bertini	Via Bertini
Car access	No	Via Egeo	No	No	Via Montefeltro	Via Montefeltro	No
Structure	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete
Infill	Masonry/plaster	Brick Masonry/plaster	Brick Masonry/plaster	Brick Masonry/plaster	Brick Masonry/plaster	Brick Masonry	Brick Masonry
Roof type	Flat	Pitched	Pitched	Pitched	Flat /skylights	Flat	Composite roof



B-II	B-III	B-IV	B-V	B-VI	C-I	C-II	C-III
Osi East	Osi East	Osi East	Osi East	Osi East	Ghia	Ghia	Ghia
1936	1940	1940	1961	1980	1958	1958	1936
Jacazio	Jacazio	Jacazio	N. Diulgheroff	-	N. Diulgheroff	N. Diulgheroff	-
7148 sqm	2555 sqm	556 sqm	541 sqm	1007 sqm	3968 sqm	407 sqm	304 sqm
1	1	1	2	1	1-2	2	2
Production Line	Press Department	Accessory Rooms	O.S.I-GHIA offices	Warehouse	Office,Warehouse	Ghia Offices	Ghia Offices
No	Asbestos Removed	No	No	Asbestos Removed	Yes	Yes (capping)/asbestos	Yes (capping)/asbestos
Abandoned	Abandoned	Abandoned	Abandoned	Abandoned	Abandoned	Abandoned	Abandoned
Europa Risorse SGR	Europa Risorse SGR	Europa Risorse SGR	Europa Risorse SGR	Europa Risorse SGR	Europa Risorse SGR	Serenissima SGR	Europa Risorse SGR
Corso Dante	Via Montefeltro	No	Via Montefeltro	No	Via Montefeltro	Via Montefeltro	Via Montefeltro
Corso Dante	Via Montefeltro	No	No	No	Via Montefeltro	Via Montefeltro	No
Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete	Steel beams and pillars	Reinforced concrete	Reinforced concrete	Reinforced concrete
Masonry/plaster	Masonry/plaster	Brick Masonry/plaster	Brick Masonry/Klinker	Glass walls	Brick Masonry	Brick Masonry	Brick Masonry
Sheds	Vaulted	Flat	Flat	Shed	Vaulted	Pitched	Pitched

Environmental Analysis
Impacts of climate change

The environmental analysis explores firstly the urban level characteristics related to the climate change challenges and the related main concerns for the city of Turin, namely: the urban heat island (UHI) (figure 58, figure 62) and runoff water. In addition, further detailed research has been carried out to demonstrate the site specific features related to the research site.

In recent years, the effects resulting from the impacts of climate change have been increasingly evident. There have been increasing extreme phenomena, specifically heat waves and floods (Legambiente 2020), which have caused extensive damage to the city, its population and its economy (Arpa 2020b). The growing trend of UHI and the issues of flooding due to the morphology of the city and the critical role of recent urbanization illustrate that variations in design strategies may be helpful for the mitigation of destructive patterns. Therefore, the events of extreme temperature and heat stress, the impacts of extreme precipitation events as well as the future climate scenarios are actual matters to be discussed in design field.

In this respect, the urban level investigation incorporates the past and future climate patterns, climate impact and risks, with a narrow focus on the variations of the air temperature and precipitation patterns according to the data from Euro-mediterranean center for climate change (CMCC). The main focus is on two: RCP4.5 “Scenario with climate policies” and RCP8.5 “scenario without climate policies ”,scenarios created by the Intergovernmental Panel on Climate Change (IPCC). The climate analysis, therefore, provides a detailed representation of the current and expected climate for Turin, using a series of indicators defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), to characterize the climate and its evolution, such as the trend temperature (figure 59-64) and precipitation (figure 65-69) on an annual and seasonal scale. As represented in the graphs, the temperature has a statistically significant growth trend while for the precipitation there is no statistically significant trend.

The site specific features analysis detail out the various characteristics of the site, such as the potential air temperature, surface temperature, wind speed and predicted mean vote related to the research site, using specific tools represented later in this section (figure 83-90).

Besides, the potential engagement of the site into the flows of runoff water, the affected areas and collecting basind are investigated due to collected data, site inspections and calculations, introducing water harvesting strategies (figure 73, figure 74).

To conclude, the site specific features analysis reveals the details related to the contamination of the land as a result of the previous industrial activities, discussing the type, level, depth and location of contaminants and applied remediations (figure 70, figure 71).

This section is aimed at evaluating the main local impacts of climate change on which adaptation strategies may be developed.

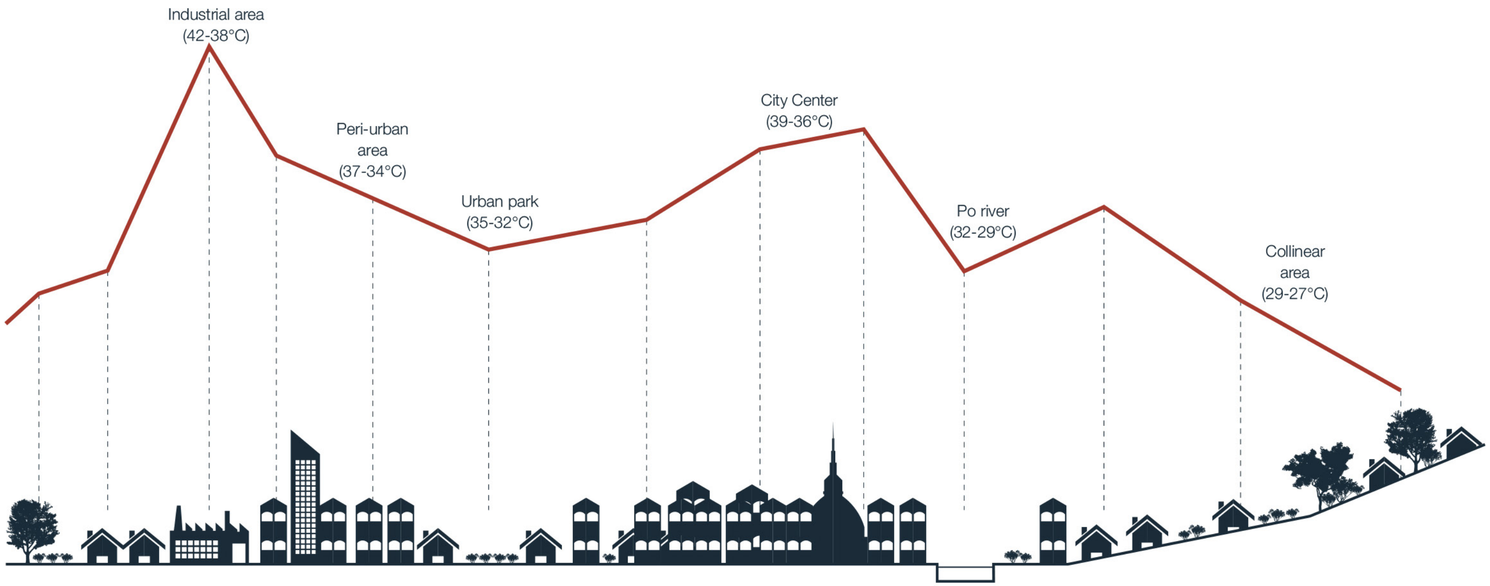
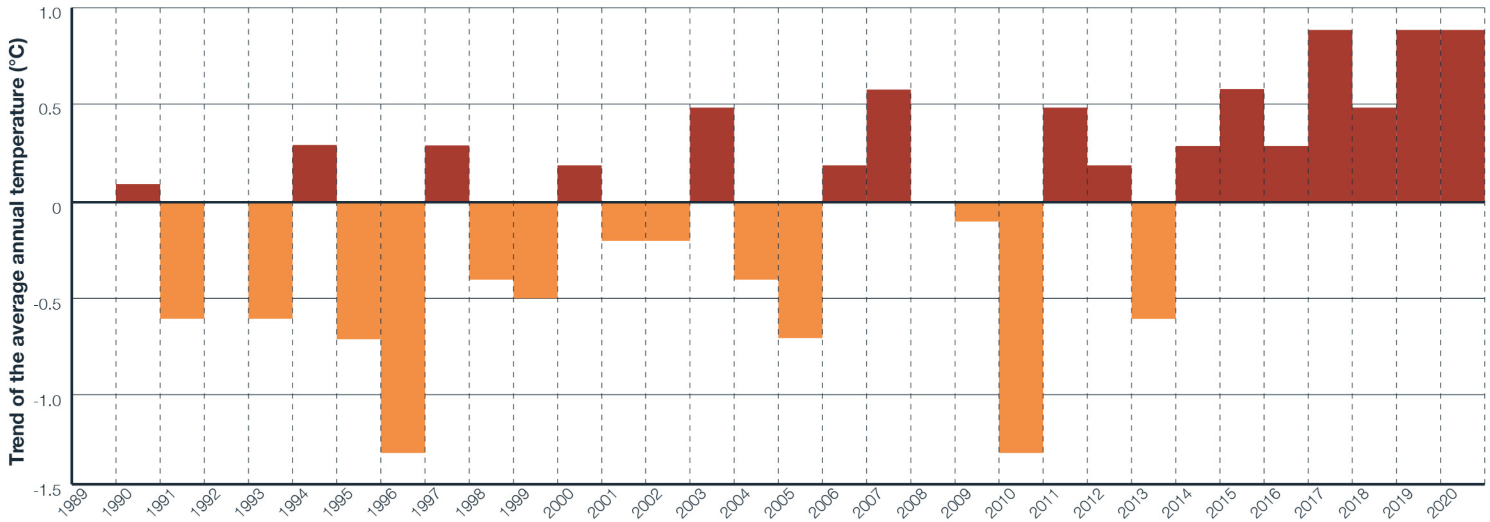
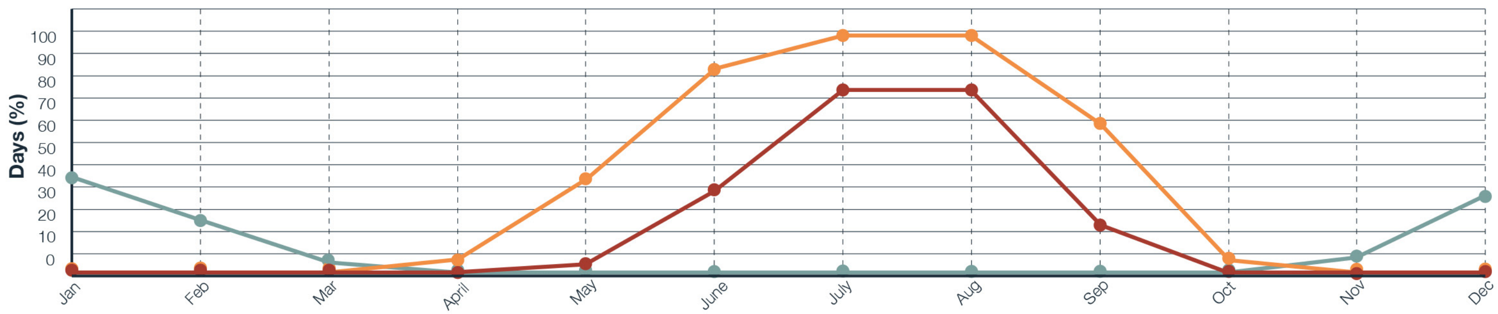


FIGURE 58:
Temperature variation for different urban fabrics.
Source: EPA

Variation of Temperature and Urban Hit Island in Turin





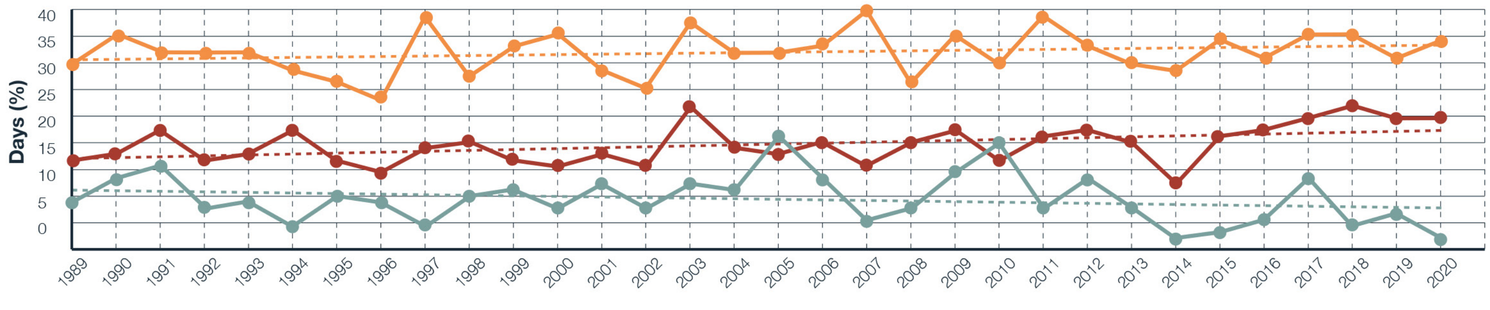


FIGURE 59:
Trend of the average annual temperature anomaly calculated with respect to the average annual temperature over the period 1989-2020.
Source: CMCC Report Torino

FIGURE 60:
Representation of the annual cycle (percentages of days per month) for the indicators described as cold days (frost days, FD), hot nights (tropical nights, TR) and very hot days (summer days, SU) over the period 1989 -2020.
Source: CMCC Report Torino

FIGURE 61:
Annual annual trend (percentages of days per year) for the indicators described as cold days (frost days, FD), hot nights (tropical nights, TR) and very hot days (summer days, SU) over the period 1989 -2020.
Source: CMCC Report Torino

LEGEND

Cold days
Very hot days
Hot nights

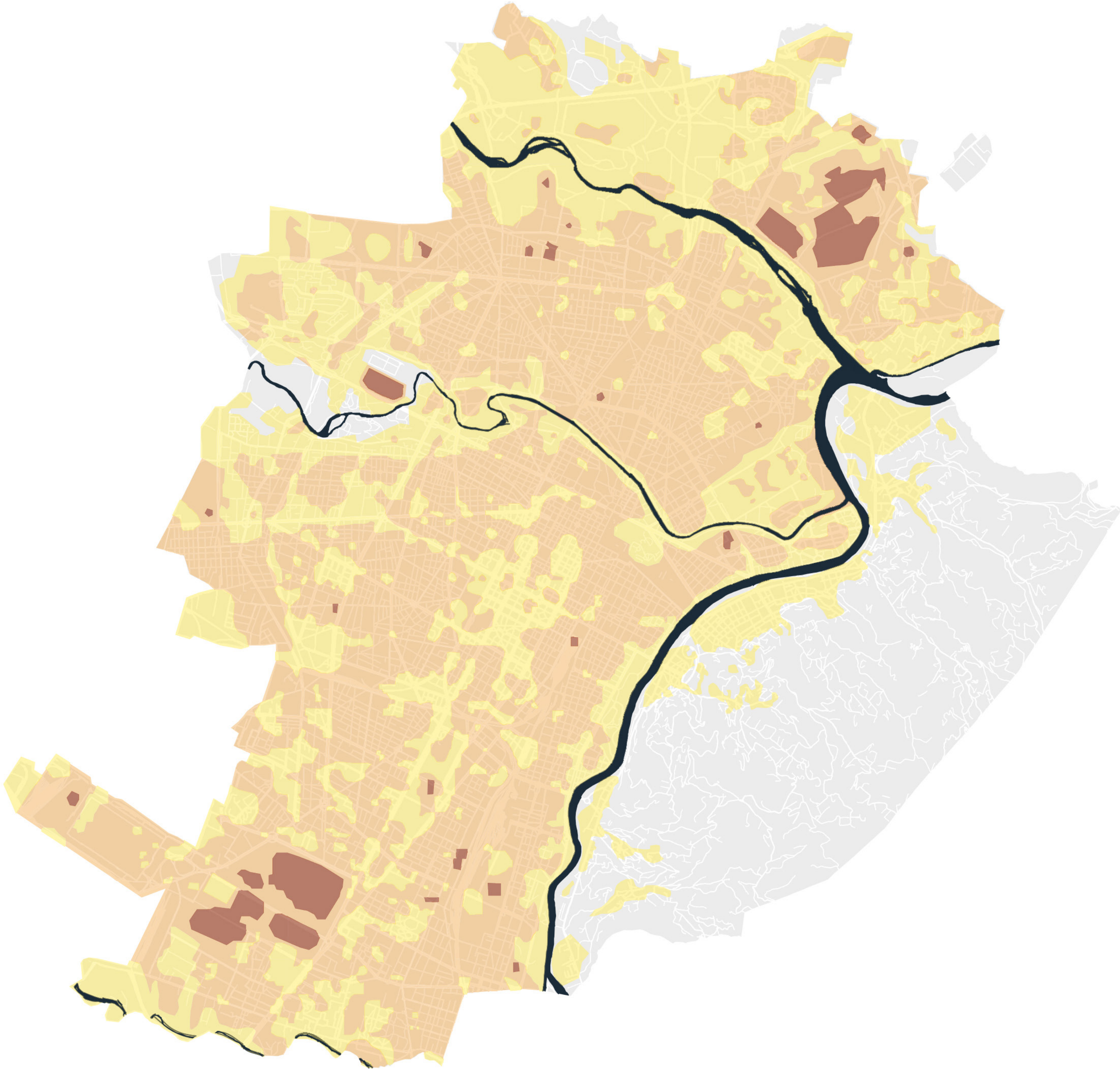


FIGURE 62:
Urban Heat Island Hazard in Turin
Source: Comune di Torino (2015), Landsat (NASA 2015), ASTER (NASA/MET, 2006), GeoAdaptive (2017)

LEGEND

Heat Hazard Severity

- *Low (+-1SD)*
- *Moderate (1-2 SD)*
- *High (>2 SD)*

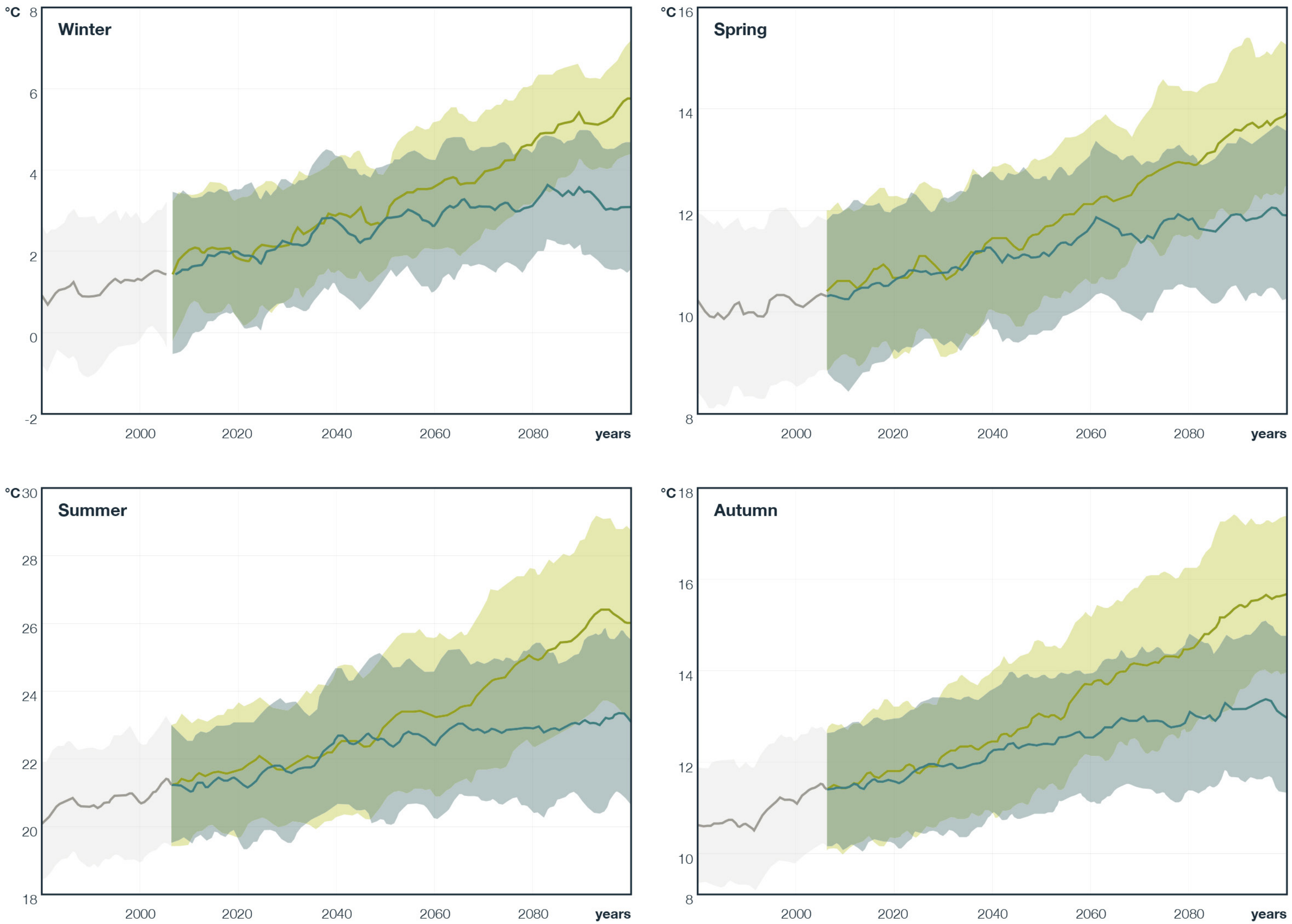


FIGURE 63:
Changes in the seasonal average temperature for the EURO-CORDEX models.
Source: CMCC Report Torino

LEGEND

EURO-CORDEX historical
EURO-CORDEX RCP4.5
EURO-CORDEX RCP8.5

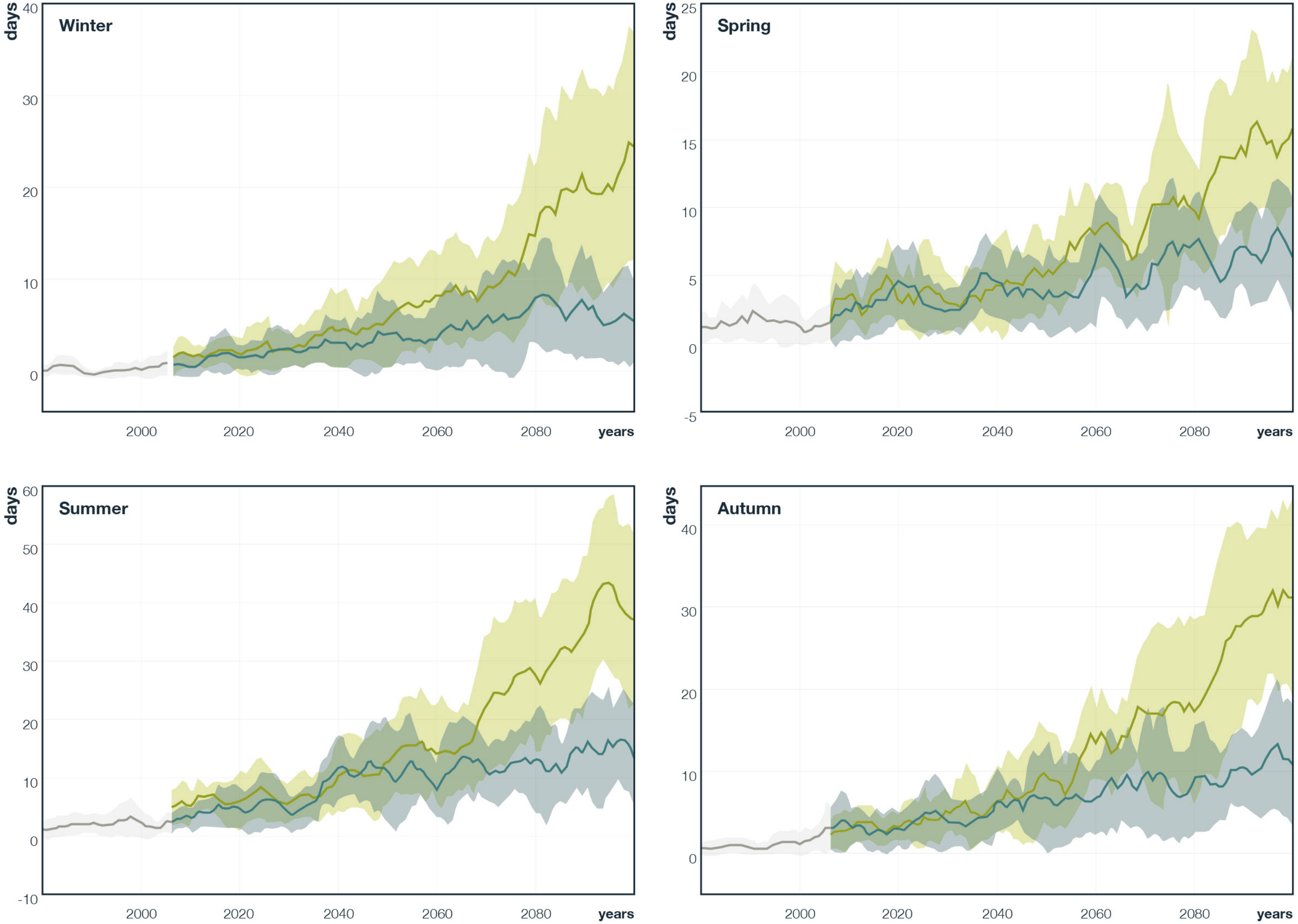
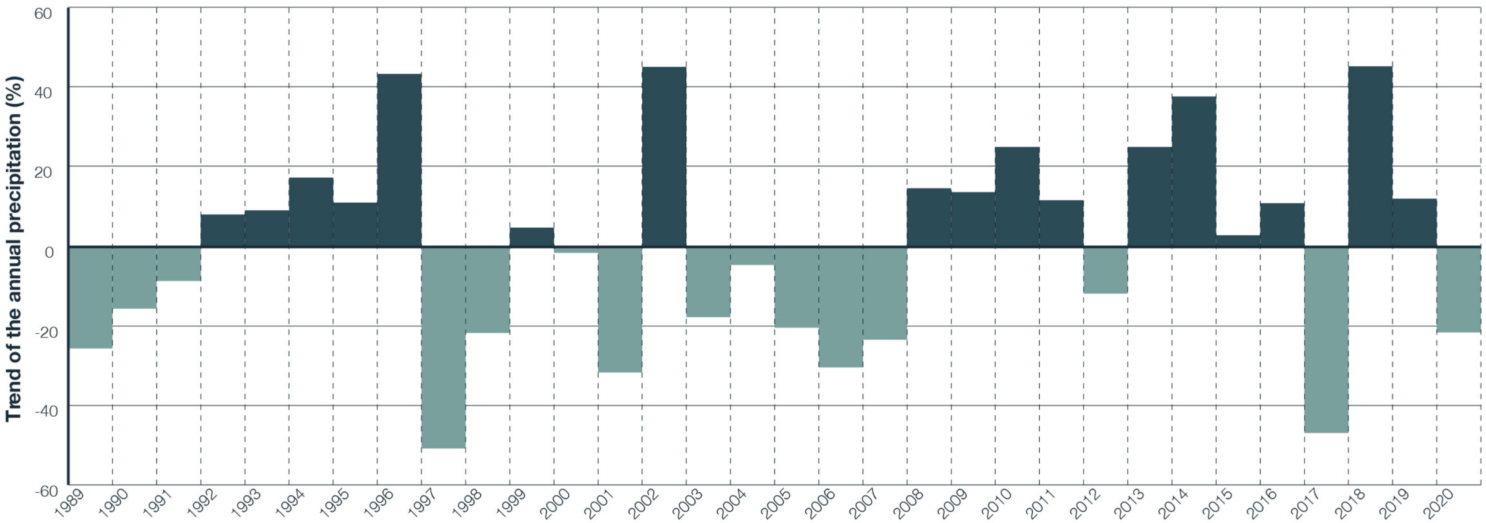


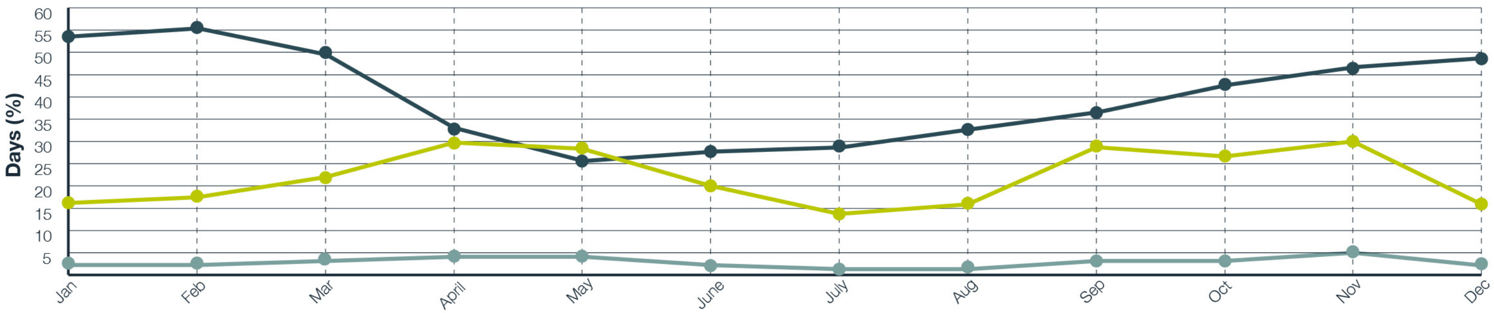
FIGURE 64:
Changes in the number of very hot days (WSDI) indicator for EURO-CORDEX models. Source: CMCC Report Torino

LEGEND

- *EURO-CORDEX historical*
- *EURO-CORDEX RCP4.5*
- *EURO-CORDEX RCP8.5*

Precipitations and run-off water in Turin





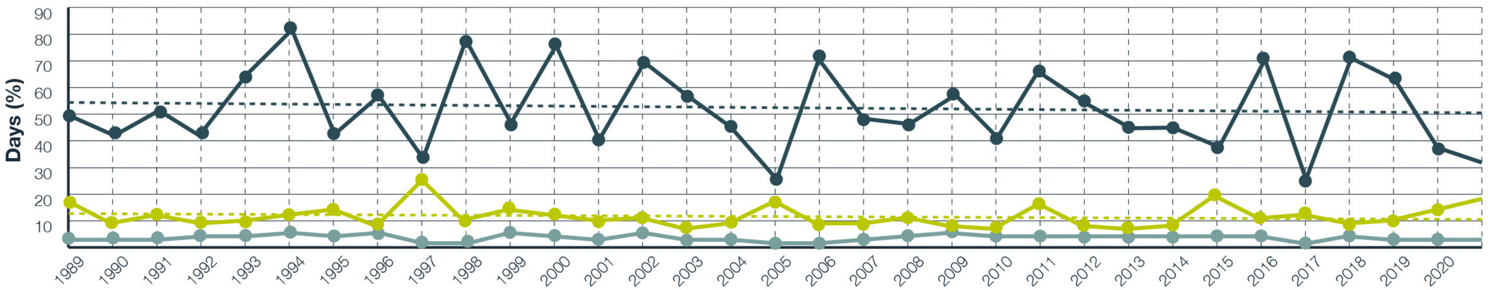


FIGURE 65:
Trend of the annual precipitation anomaly calculated with respect to the average annual precipitation over the period 1989-2020.
Source: CMCC Report Torino

FIGURE 66:
Annual cycle of indicators relating to heavy rainfall (R20), maximum number of consecutive days without rain (CDD), both calculated in terms of percentage of days per month, and maximum daily rainfall values (RX1day), over the period 1989-2020.
Source: CMCC Report Torino

FIGURE 67:
Annual evolution of the indicators relating to heavy rains (R20) maximum number of consecutive days without rain (CDD), both calculated in terms of percentage of days per month, and maximum daily values (RX1DAY), over the period 1989-2020.
Source: CMCC Report Torino

LEGEND

- *Intense precipitation*
- *Consecutive days without rain*
- *Maximum daily values*

FIGURE 68:
Percentage change expected for the future horizon 2071-2100, compared to the reference period 1971-2000, provided by the Water Quantity Indicators for Europe dataset. Source: CMCC Report Torino

LEGEND

Q100 Change (%)

- *>250*
- *200-250*
- *150-200*
- *100-150*
- *50-100*
- *0-50*
- *<0*

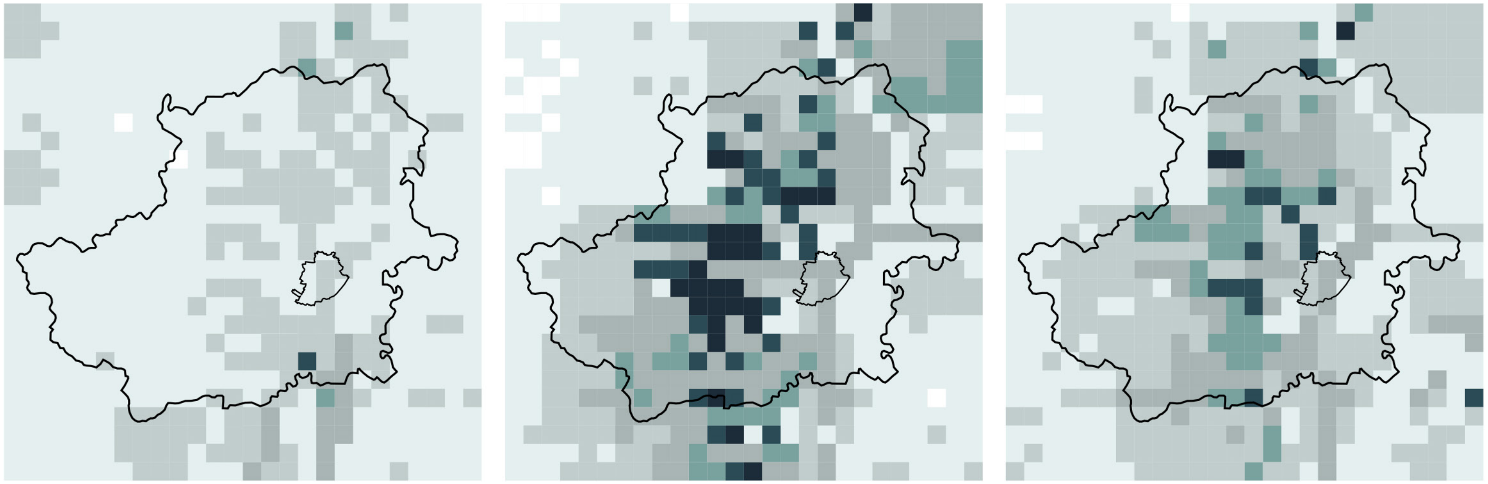


FIGURE 69:
Percentage variation of the annual maximum daily flow rate for various return periods T and for different future time horizons with respect to the reference period 1971-2000. The values are obtained considering the ensemble mean, and are averaged between different hydrological models available. Source: CMCC Report Torino

Scenario	RCP 2.6			RCP 4.5			RCP 8.5		
Horizon Thunderstorm	2011-2040	2041-2070	2070-2100	2011-2040	2041-2070	2070-2100	2011-2040	2041-2070	2070-2100
T- 2 years	20.00	22.38	12.25	20.00	31.63	43.13	24.38	40.50	32.38
T- 5 years	32.75	28.88	27.25	29.88	53.88	74.88	42.88	64.88	59.38
T- 10 years	38.13	31.88	34.00	34.00	63.75	89.13	51.13	76.13	71.50
T- 50 years	46.50	36.25	43.50	40.50	78.13	109.50	63.38	92.00	89.38
T- 100 years	48.88	37.38	46.50	42.25	82.75	115.75	67.00	96.75	94.63

Contamination
Site specific features

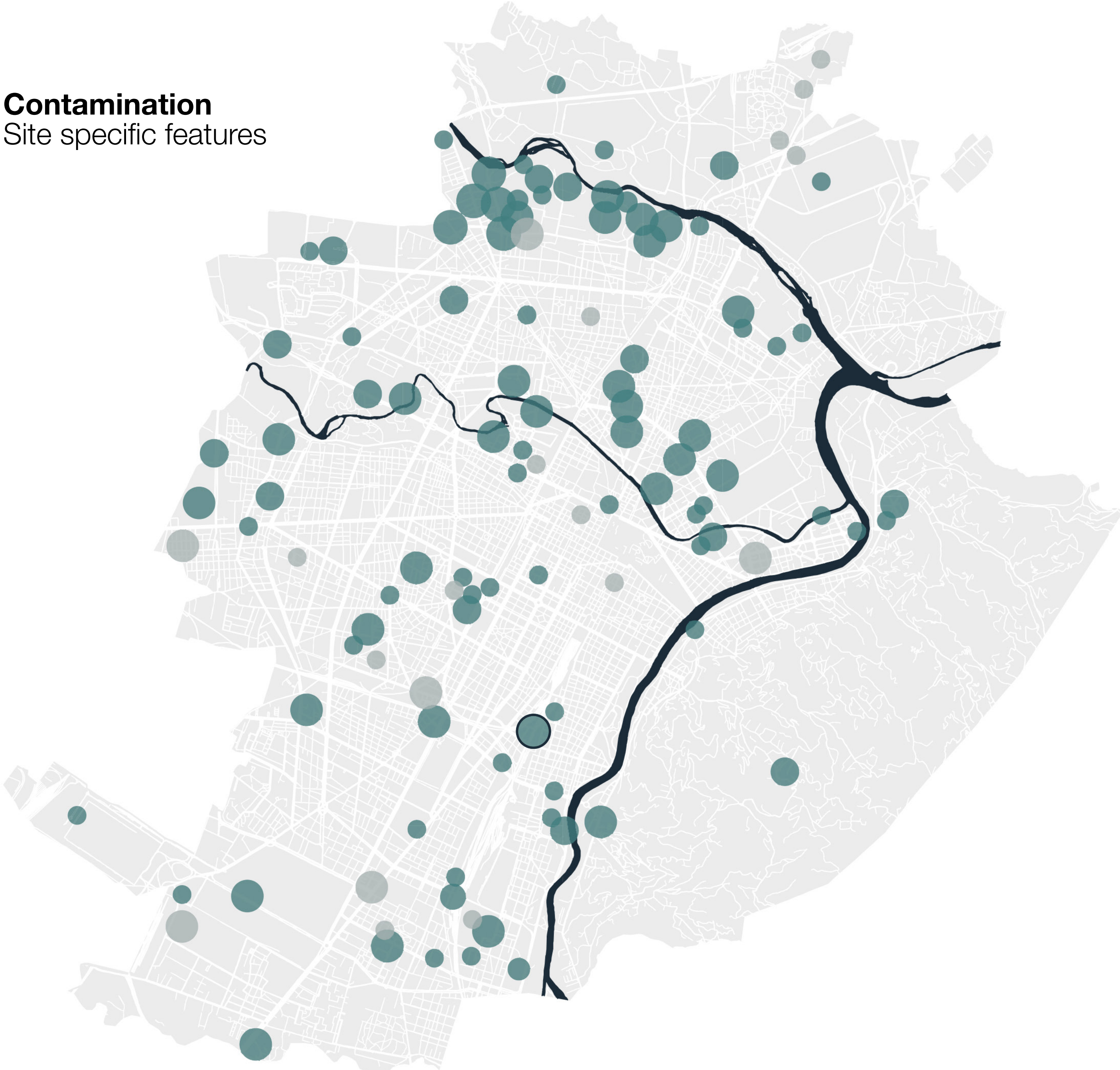
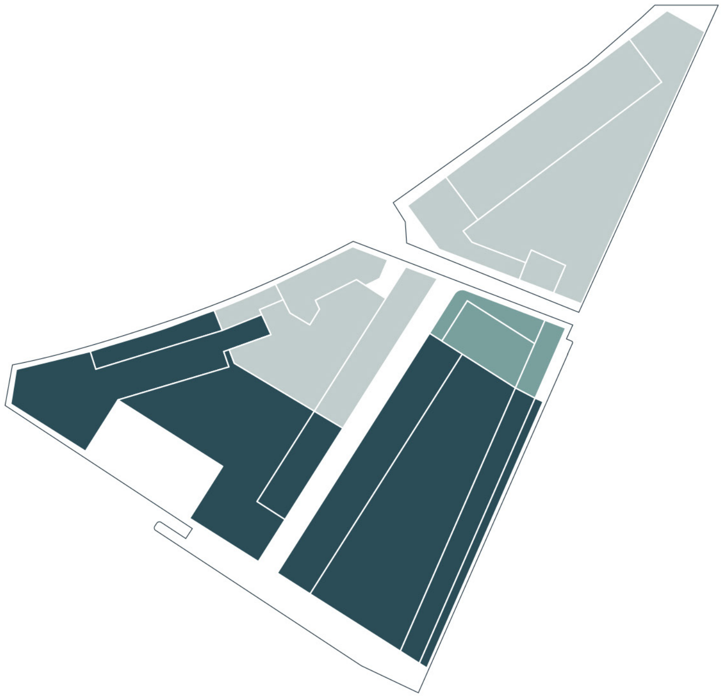


FIGURE 70:
Contaminated sites of Turin
Source: La stampa, https://www.lastampa.it/torino/2021/08/03/news/i-103-siti-inquinati-di-torino-divisi-per-quartiere-1.40564360

LEGEND

To be reclaimed (103 sites)
Reclaimed (21sites)



	Soil	Subsoil	Groundwater
Aromatics	●	●	
Inorganic compounds	●	●	●
Metals	●	●	●
Dioxins	●		
Furans	●		
Hydrocarbons	●	●	
Polycyclics	●	●	
Chlorinated aliphatic compounds			●

FIGURE 71:
Site remediation mapping and existing contamination data.
Source: Turin Municipality, La stampa

LEGEND

Total remediation applied
Partial remediation applied
No remediation applied

The former OSI Ghai area is among many other former industrial areas labeled as contaminated sites of Turin (figure 70), and despite its partial remediation it is still listed among the sites which yet should be reclaimed. Figure 71 illustrates the existing situation of appied remediation in the area, which has been developed for separate portions during distinct projects. Initially the area owned by Societa Montefeltro Srl in OSI West area, and then the entire Ghia area and some portions of OSI East area, owned by Società Europa Risorse SGR, have undergone a cleaning and remediation process using various techniques such as capping.
However, a considerably vast area still remains untouched, and is subjected to a close attention and proper strategies for further development projects, considerig the hazardous impact and potential costs. The former industrial processes and mismanagement of the building structures have been identified as the causes of the present contamination, which has appeared in various layers including the soil, subsoil and groundwater, represented in the table on this page (La stampa 2021).

Water harvesting
Calculation of the volume

Discussions around the issues related to the uncontrolled runoff water as one of the main environmental concerns in the city of Turin, result in the increasing importance of water harvesting strategies.
This section focuses on the site potentials for water harvesting by analyzing two distinct areas: the annual precipitation volume and the site specific features.
In this respect the minimum and maximum monthly rainwater yield have been calculated for the existing situation of the project area as well as for the projected interventions (table1), according to the data collected from the stations in Turin, in order to have a clear idea about the volume of the water deriving from precipitation. An approximate prediction of this amount for the future can be estimated by the data represented in the table on the next page for the period 2036-2065 (CMCC).
Additionally, the rain water flow investigation diagram based on site inspection illustrates the existing situation of draining systems, water flow directions and potential water collecting basins in the area due to various circumstances, such as missing draining pipes of the roofs, penetration due to missing structure, ground slope, etc (figure 73).
The project will be developed based on these investigations in order to achieve the optimal result for the runoff water management in each phase. It aims to develop a water harvesting system which will collect, filter and recycle the water, preventing the runoff and providing a water source for the secondary use and irrigation of the green spaces suggested in the design. Besides, the water collecting basins will be integrated in the design of the recreation areas, becoming home for some species and elements of biophilic design in public spaces (figure 74).

W_{ry} = monthly rainwater yield [l/month]

$$\mathbf{W_{ry} = A_c \times e \times h_N \times \eta}$$

A_c = roof collecting area [m^2]

Existing situation 32400 m^2

e = yield coefficient

Slanted hard roof 0.8
Flat roof, without gravel 0.8
Flat roof, with gravel 0.6
Green roof, intensive 0.3
Green roof, extensive 0.5
Paved surface/compound paved surface 0.5
Asphalt covering 0.8
Bare Earth – 0.35-0.55
Grass – 0.10-0.25
Sand – 0.30-0.50
Asphalt and Concrete – 0.80-0.90
Metal – 0.95

h_N = monthly precipitation [l/m^2 or mm/month]

Average monthly precipitation [mm] in Turin:

December (minimum) = 45,1

May (maximum) = 145,3

η= hydraulic filter efficiency

Minimum rainwater yield for the existing situation
= 1,464,126 [l/month]

Maximum rainwater yield for the existing situation
= 4,717,019 [l/month]

Minimum rainwater yield after interventions
= 1,188,179 [l/month]

Maximum rainwater yield after interventions
= 3,827,992 [l/month]

The values reported by the single COSMO CLM model for the period 2036-2065 consider different scenarios, one with climate policies, demonstrating slightly positive variations for maximum daily rainfall for all seasons, and one without climate policies in which the increase in daily maximum rainfall is generally reported in the spring and winter, with a decrease in the summer.

Scenario	RCP 4.5		RCP 8.5	
Season	Expected change %	Range of uncertainty %	Expected change %	Range of uncertainty %
Winter	+12	±14	+3	±11
Spring	-2	±9	+7	±12
Summer	+3	±14	+4	±18
Fall	+6	±8	+10	±11

FIGURE 72:
Table for expected average variation on the domain of interest provided by the EURO-CORDEX ensemble and relative uncertainty estimate, for the two concentration scenarios and the different seasons, for the RX1DAY indicator, maximum daily precipitation.
Source: CMCC Report Torino

Water harvesting
Analysis of flows

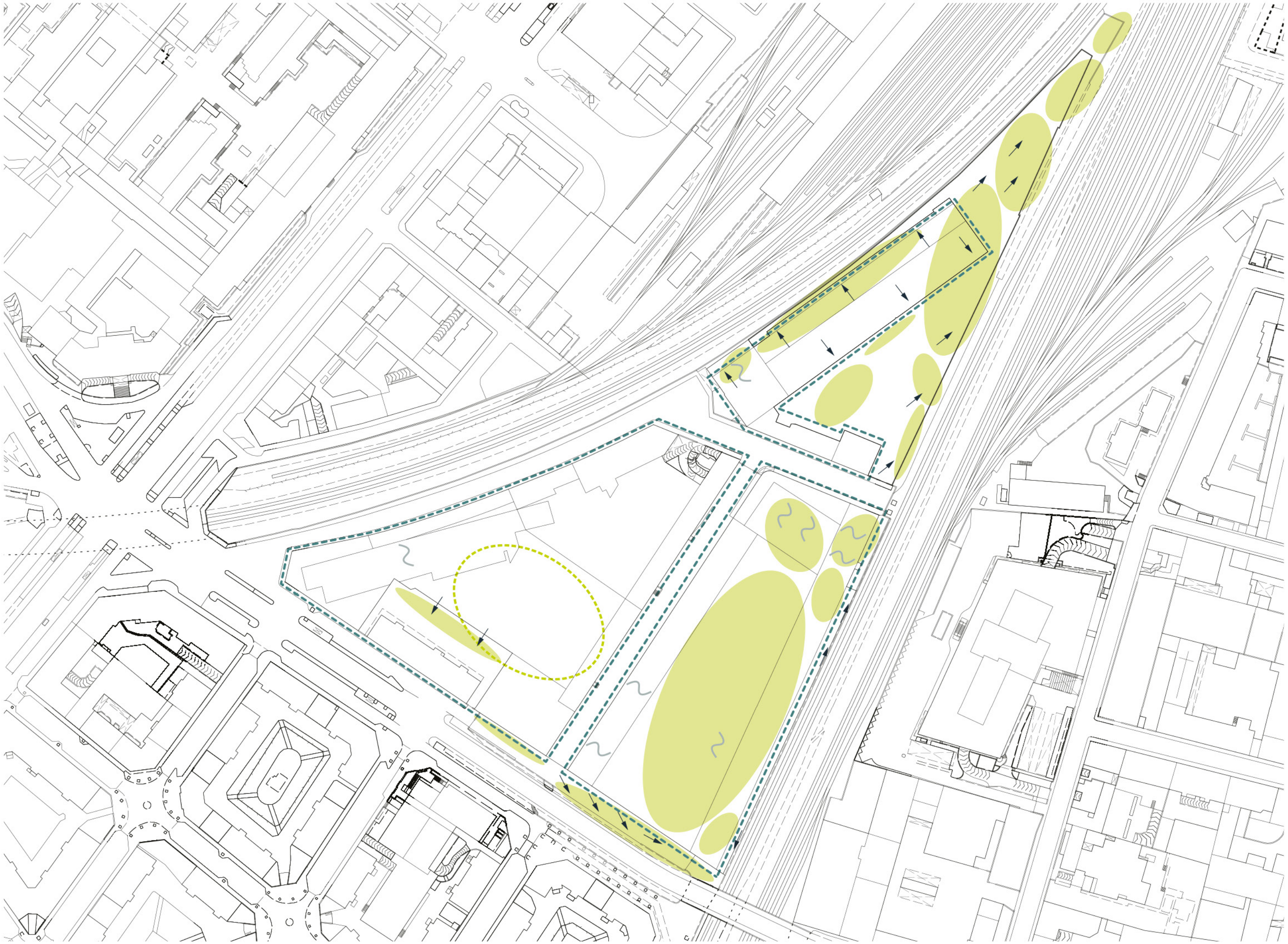


FIGURE 73:
Water flow mapping

LEGEND

Run off water basins
Projected run off water basin
Existing roof drainage
Water flow direction
Penetration due to missing roof

FIGURE 74:
Water harvesting diagram

Precipitation
The seasonal source of water

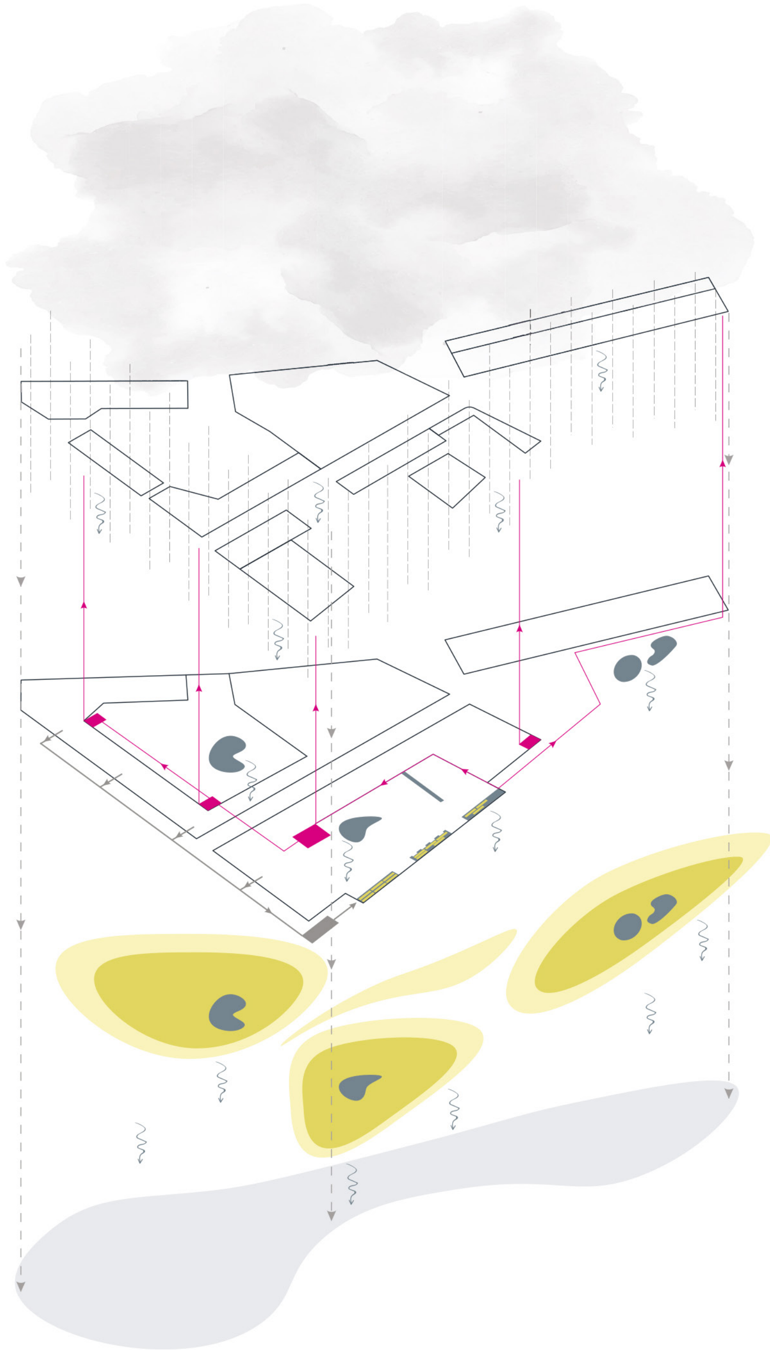
Collecting rainwater
Implementing organized roof drainage systems

Collecting surface water
Implementing canals and infiltration basins / detention ponds.

Collecting gray water
The permanent source of water

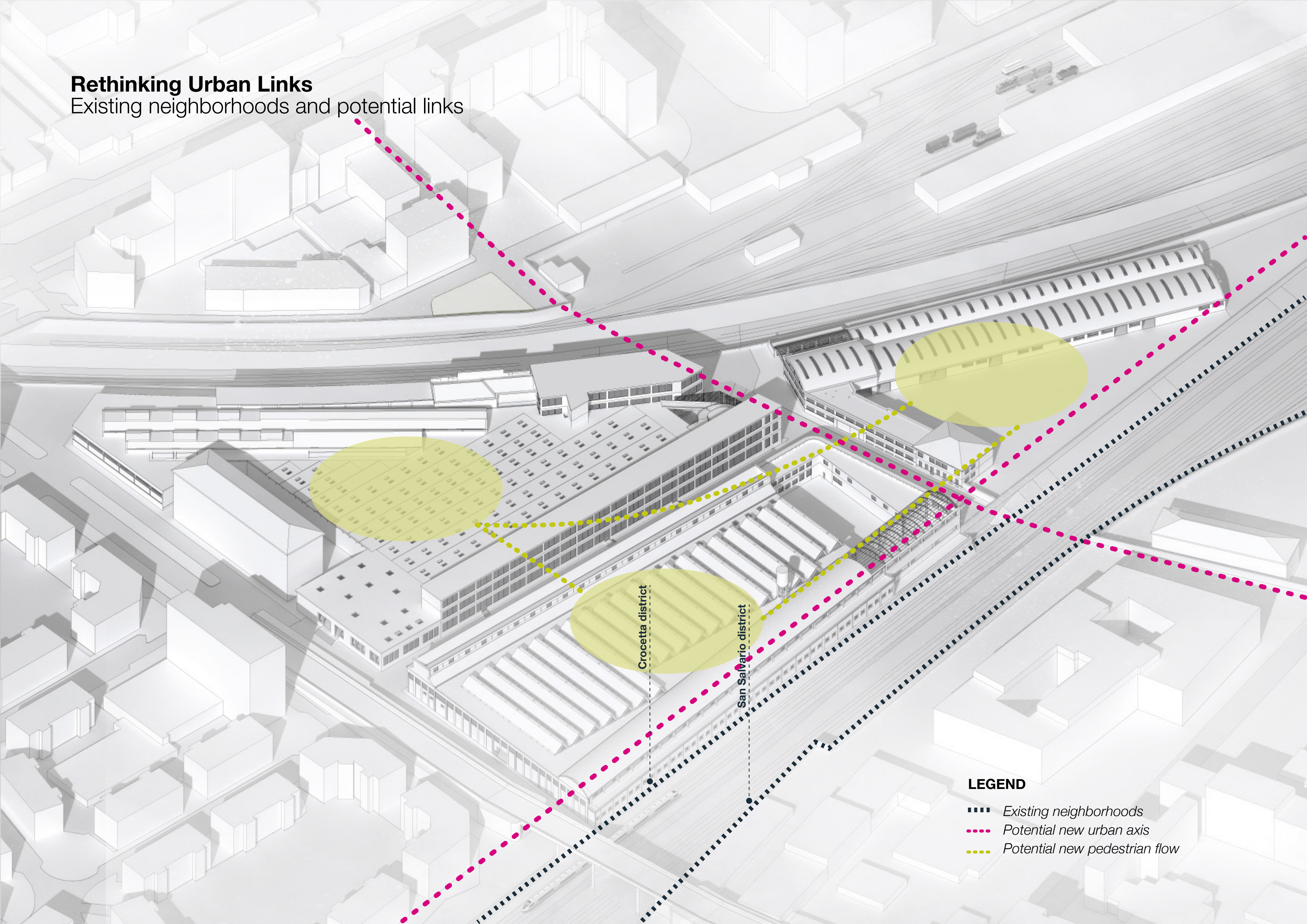
Recycling
Irrigating the gardens and green spaces

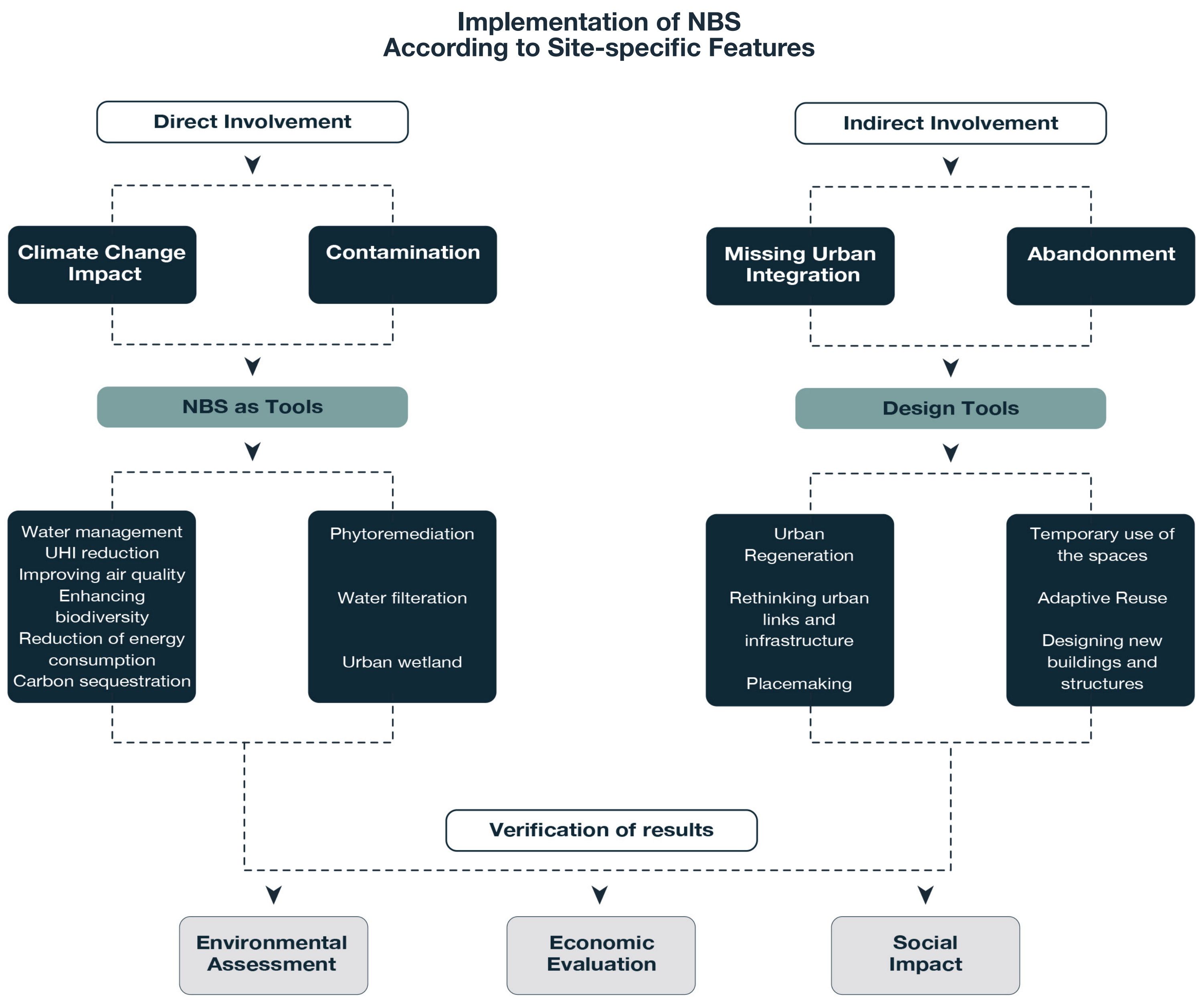
Infiltration
Refilling aquifers through the rain gardens

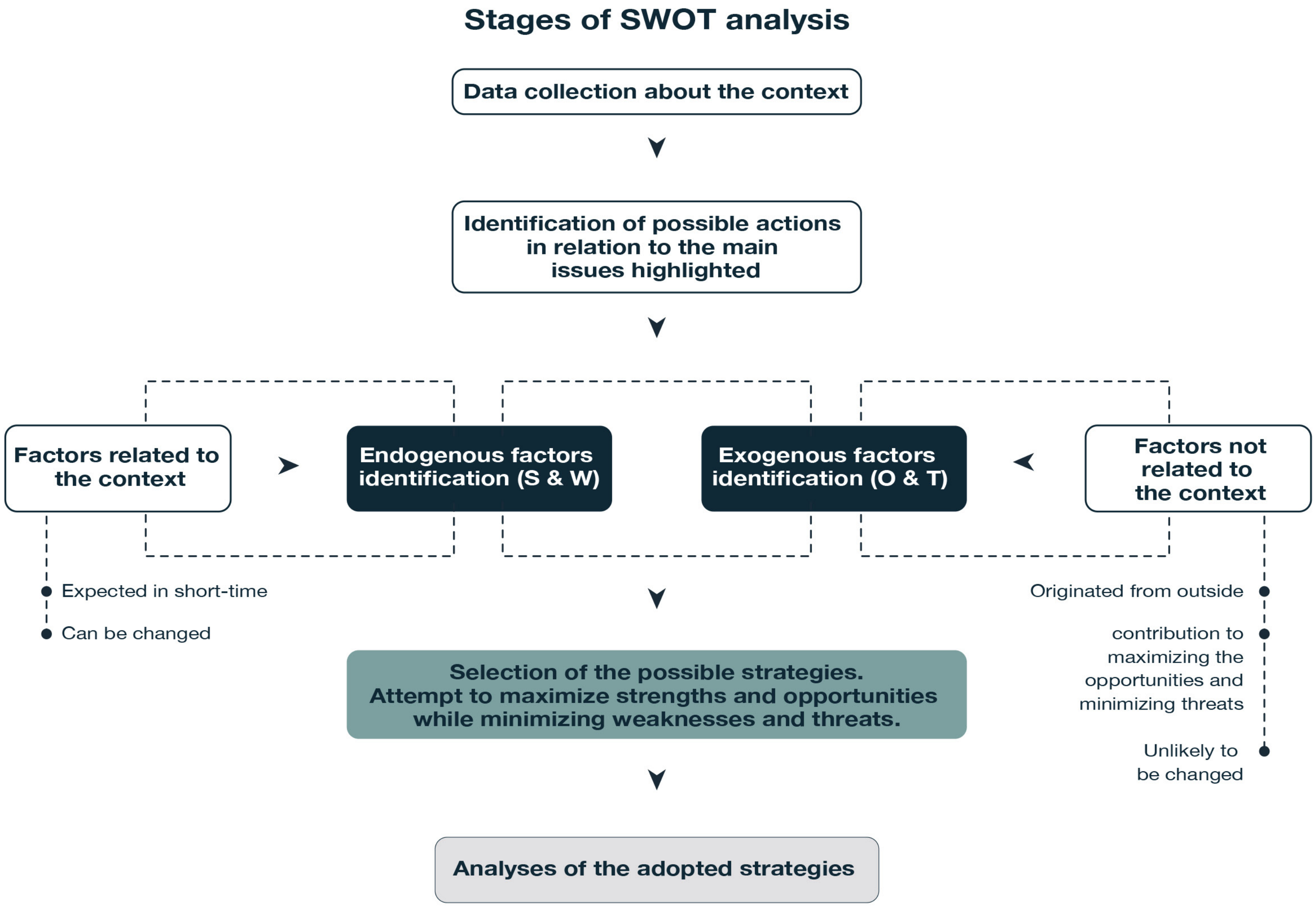


Rethinking Urban Links

Existing neighborhoods and potential links




Implementation of NBS
According to Site-specific Features
Direct Involvement
Climate Change Impact
Contamination
NBS as Tools
Water management
UHI reduction
Improving air quality
Enhancing biodiversity
Reduction of energy consumption
Carbon sequestration
Phytoremediation
Water filteration
Urban wetland
Indirect Involvement
Missing Urban Integration
Abandonment
Design Tools
Urban Regeneration
Rethinking urban links and infrastructure
Placemaking
Temporary use of the spaces
Adaptive Reuse
Designing new buildings and structures
Verification of results
Environmental Assessment
Economic Evaluation
Social Impact


Stages of SWOT analysis
Data collection about the context
Identification of possible actions in relation to the main issues highlighted
Factors related to the context
Endogenous factors identification (S & W)
Exogenous factors identification (O & T)
Factors not related to the context
Expected in short-time
Can be changed
Originated from outside
contribution to maximizing the opportunities and minimizing threats
Unlikely to be changed
Selection of the possible strategies. Attempt to maximize strengths and opportunities while minimizing weaknesses and threats.
Analyses of the adopted strategies

S W O T

Strengths

Spatial and Regulatory Dimension:
- Industrial legacy/local Identity
- Proximity to the city center
- Unused Building stock

Socio-cultural Dimension:
- Sense of belonging
- Labor potential for the developing sectors

Environmental Dimension:
- Potential space to be converted into green
- Potential space for water harvesting

Functional and Economic Dimension:
- Active functions in the area

Weaknesses

Spatial and Regulatory Dimension:
- Urban decay
- Insufficient infrastructure
- Insufficient accessibility
- Land ownership structure
- Lack of upgraded PRG

Socio-cultural Dimension:
- Lack of sense of security
- Lack of community support
- Insufficient public awareness

Environmental Dimension:
- Lack of managed urban green
- Urban heat island
- Lack of run-off water management
- Endangered biodiversity
- Industrial contamination

Functional and Economic Dimension:
- Lack of mixed-use
- High maintenance cost

Opportunities

Spatial and Regulatory Dimension:
- Increasing accessibility
- Preservation & reuse of Industrial heritage
Regeneration of brownfields
- New regulations for temporary use of the abandoned spaces
- New experimental approaches concerning future challenges due to lack of upgraded PRG

Socio-cultural Dimension:
- Increasing life quality (health/well-being etc.)
- Increasing sense of security
- Increasing public awareness
- Integration of communities
- New job opportunities

Environmental Dimension:
- Adaptation & mitigation strategies responding the climate change
- Mitigation of UHI
- Water harvesting and flood control/constructed urban wetland
- Urban Agriculture
- Enhancing biodiversity
- Industrial pollution remediation
- Noise and vibration control
- Sustainable Energy

Functional and Economic Dimension:
- Private sector incentives
- Tourism incentives
-Circular economy
- Increasing land and property value

Threats

Spatial and Regulatory Dimension:
- Reluctant approach of the land owners /veto players

Socio-cultural Dimension:
- Neglecting the community in the design process

Environmental Dimension:
- Climate change/ unpredicted phenomena and patterns
- Subject of noise pollution

Functional and Economic Dimension:
- Lack of investment
- Failure in realizing previously approved development projects

Stakeholders Analysis

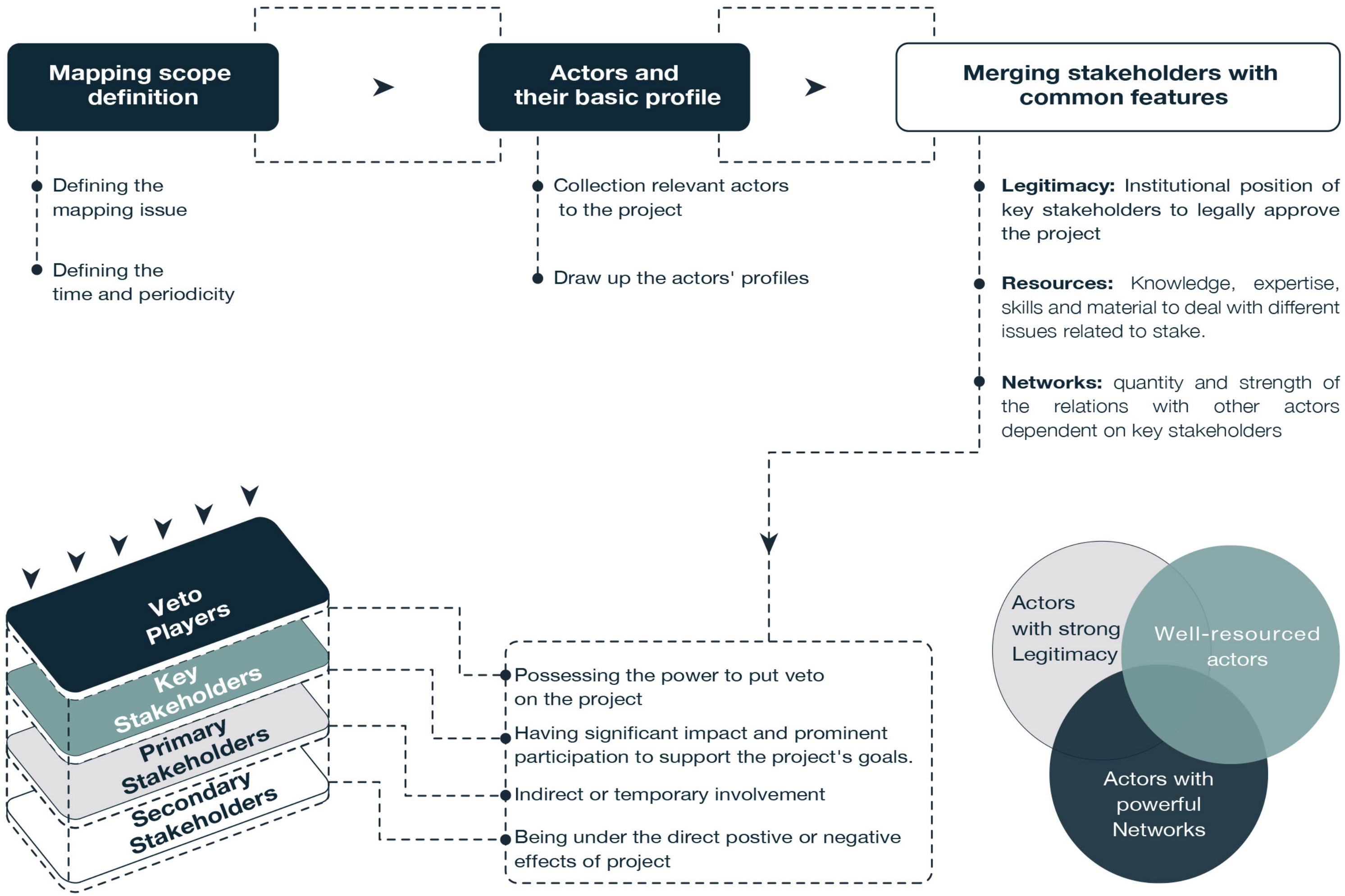


FIGURE 75:
Area division according to ownership

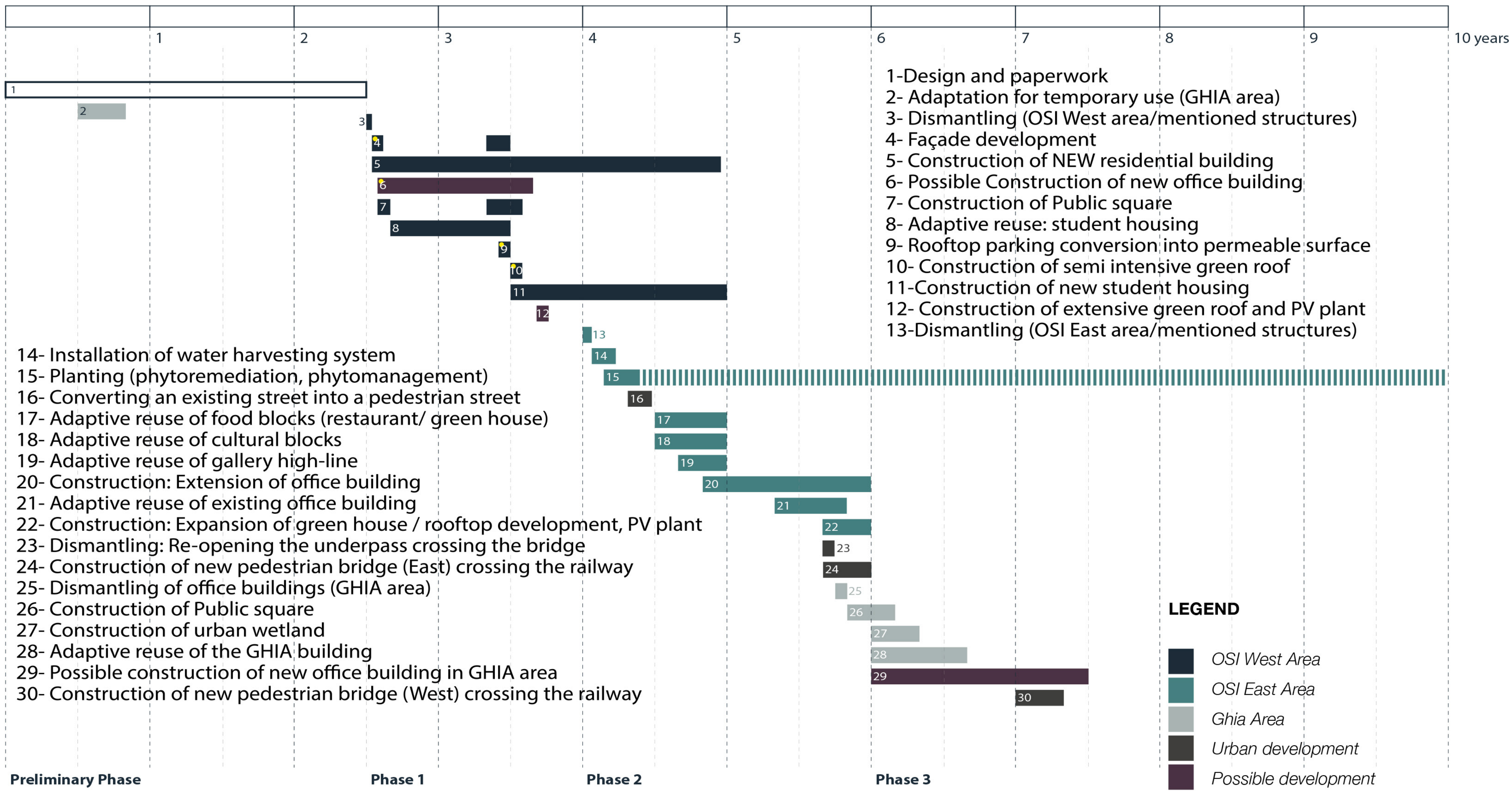
LEGEND

- *Project site owners' property*
- *Neighbourhood land ownership*
- *Project site*

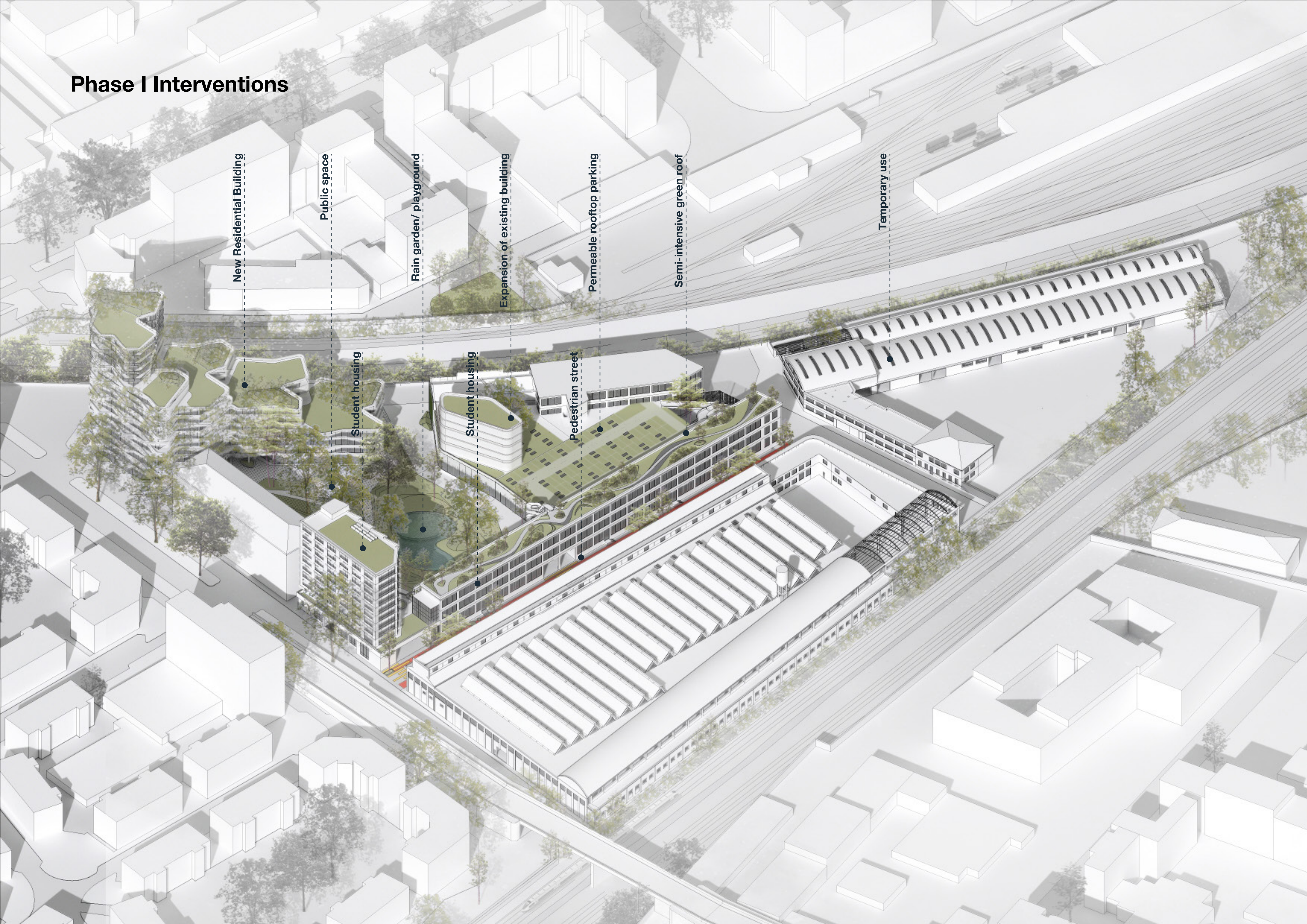
Stakeholder Analysis

N	Actor Name, function	Agenda, Mandate / mission Strategic objectives	Arena Field of action, outreach
	Private Sector		
	Key stakeholders		
VP1	Societa Europa Risorse SRL	Profitable development of property	Asset management company
VP2	Societa Montefeltro SRL	Profitable development of property	Refurbishment of abandoned industrial buildings
VP3	FS Sistemi Urbani	Profitable development of property	Railway service/ Urban regeneration
4	Private Owner of Residential Building	Increasing land value /social value/quality of life	-
5	External investors	Profit chasing investment	Investment
6	Project developers	Developing profit chasing projects	Planning & monitoring projects for companies
7	Design team	Design (income)	Design
8	Construction team	Construction (income)	Construction sector
	Secondary stakeholders		
1	Gruppo Nova coop	Possible interest for investment	Supermarket
2	Biesse Investment SRL	Possible interest for investment	Business consultancy, administrative-management consultancy and business planning
3	EDILCAM	Possible interest for investment	Design, Construction, restoration, works, energetic requalification, seismic adjustments
4	Local Businesses	Possible interest for investment	Retail and services
	Public Sector		
	Key stakeholders		
VP1	Municipality of Turin	Urban regeneration / strategic development for climate change adaptation and mitigation	Represent the community, look after its interests and promote its development
2	External investors	Profit chasing investment	Investment
	Secondary stakeholders		
1	Universities in Turin	Expansion	Providing Education
2	University of Turin	Expansion	Providing Education
	Civil society		
	Key stakeholders		
1	External investors	Profit chasing investment	Investment
	Primary stakeholders		
1	Communities	Increasing quality of life/ public spaces/ activities, Increasing social value/	Looking after common interests
	Secondary stakeholders		
1	NGOs	Income	-
2	Event organizers	Income	-
3	Freelancers & employees	Job opportunities (Income)	-
4	Students	Housing/ Education	-
5	Tourists	Experience	-

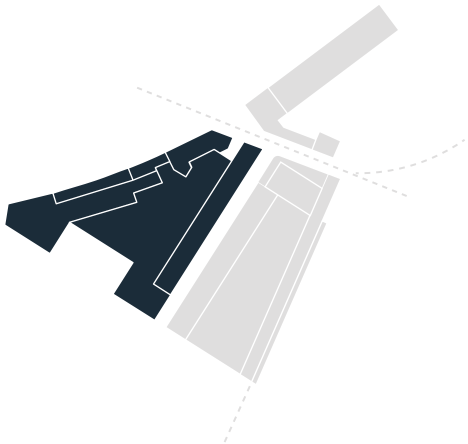
Project Development Timeline



Phase I Interventions



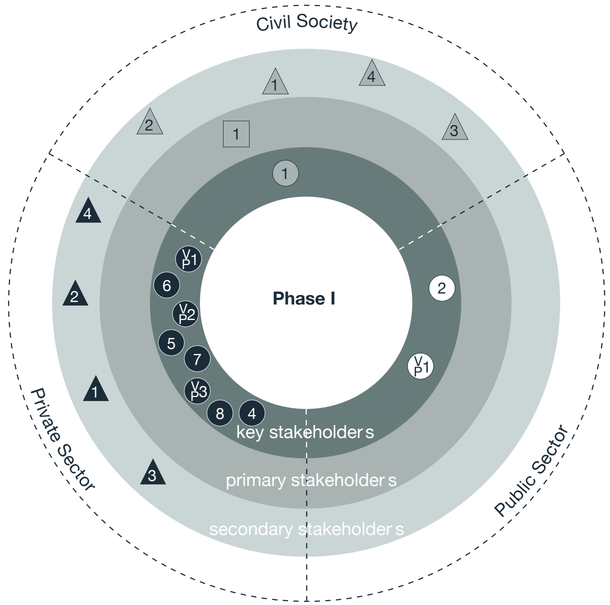
Potential Stakeholders of Phase I



VP1 - Societa Europa Risorce SRL
VP2 - Societa Montefelto SRL
VP3 - FS Sistemi Urbani
4 - Private Owner of Residential Building
5 - External investors
6 - Project developers
7 - Design team
8 - Construction team
1 - Gruppo Nova coop
2 - Biesse Investment SRL
3 - EDILCAM
4 - Local Businesses

VP1 - Municipality of Turi n
2 - External investors

1 - External investors
1 - Communities
1 - NGOs
2 - Event organizers
3 - Freelancers & employees
4 - Students



LEGEND

Primary Stakeholders
Veto Players
Secondary Stakeholders

Existing functions	**Type**
Co-working/ office spaces	Private
Rooftop parking	Private
Residential	Private

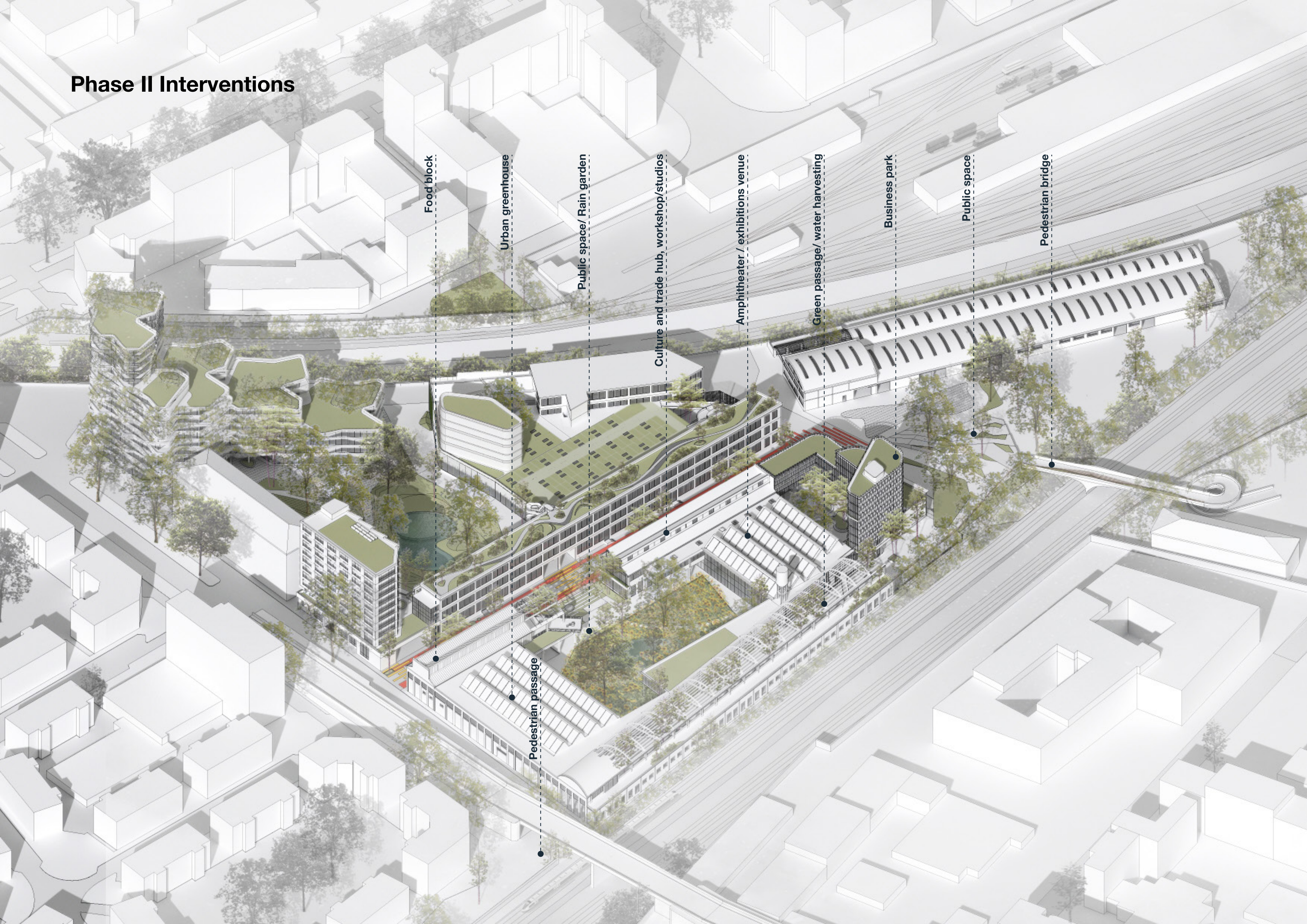
New functions	
Student housing	Private
Resiential	Private
Retail/business	Private
Rental spaces for temporary use	Private
Underground parking	Public
Public square	Public
Green roofs recreation area	Public

Construction Cost (CC)	**44,867,849**

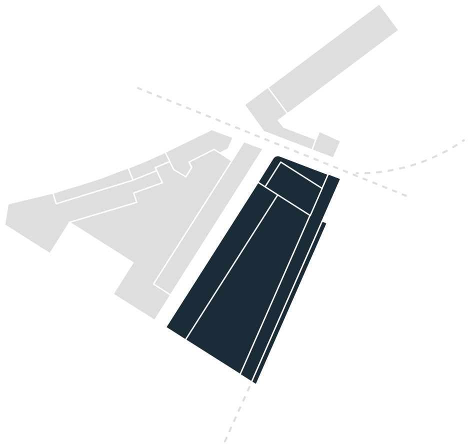
Production Cost	**60,869,519**
Works (CC)	44,867,849
Additional safety charges not to be discounted	897,357
Surveys, investigations and surveys + technical expenses design and construction supervision	4,576,521
Unexpected events	4,576,521
Acceptance of the works	457,652
VAT (value-added tax)	5,493,619

Investment cost	**72,122,709**
Production cost	60,869,519
Extraordinary maintenance	1,826,086
Loan Installment	9,427,105

Phase II Interventions



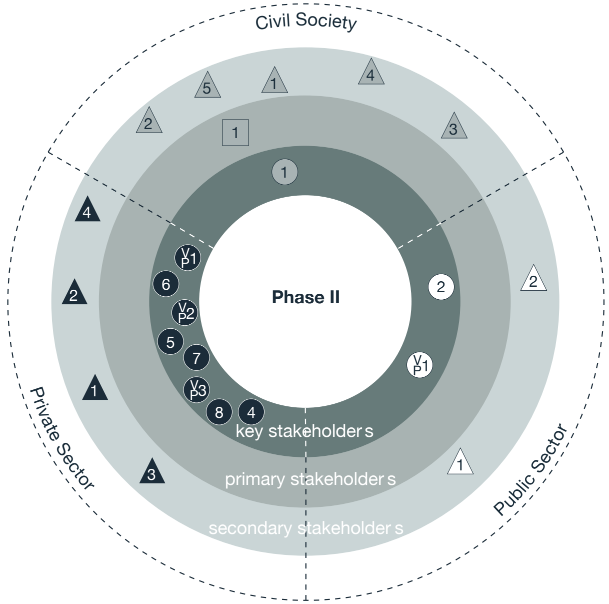
Potential Stakeholders of Phase II



VP1 - Societa Europa Risorce SRL
VP2 - Societa Montefelto SRL
VP3 - FS Sistemi Urbani
4 - Private Owner of Residential Building
5 - External investors
6 - Project developers
7 - Design team
8 - Construction team
1 - Gruppo Nova coop
2 - Biesse Investment SRL
3 - EDILCAM
4 - Local Businesses

VP1 - Municipality of Turin
2 - External investors
1 - Universities in Turin
2 - University of Turin

1 - External investors
1 - Communities
1 - NGOs
2 - Event organizers
3 - Freelancers & employees
4 - Students
5 - Tourists



New functions	Type
Water harvesting (public view)	Process
Phytoremediation (public view)	Process
Retail/business	Private
Food	Private
Rooftop green house	Private
Underground parking	Public
Public square	Public
Pedestrian Bridge	Public
Cultural block	Public
Highline passage	Public

Construction Cost (CC)	**12,299,883**

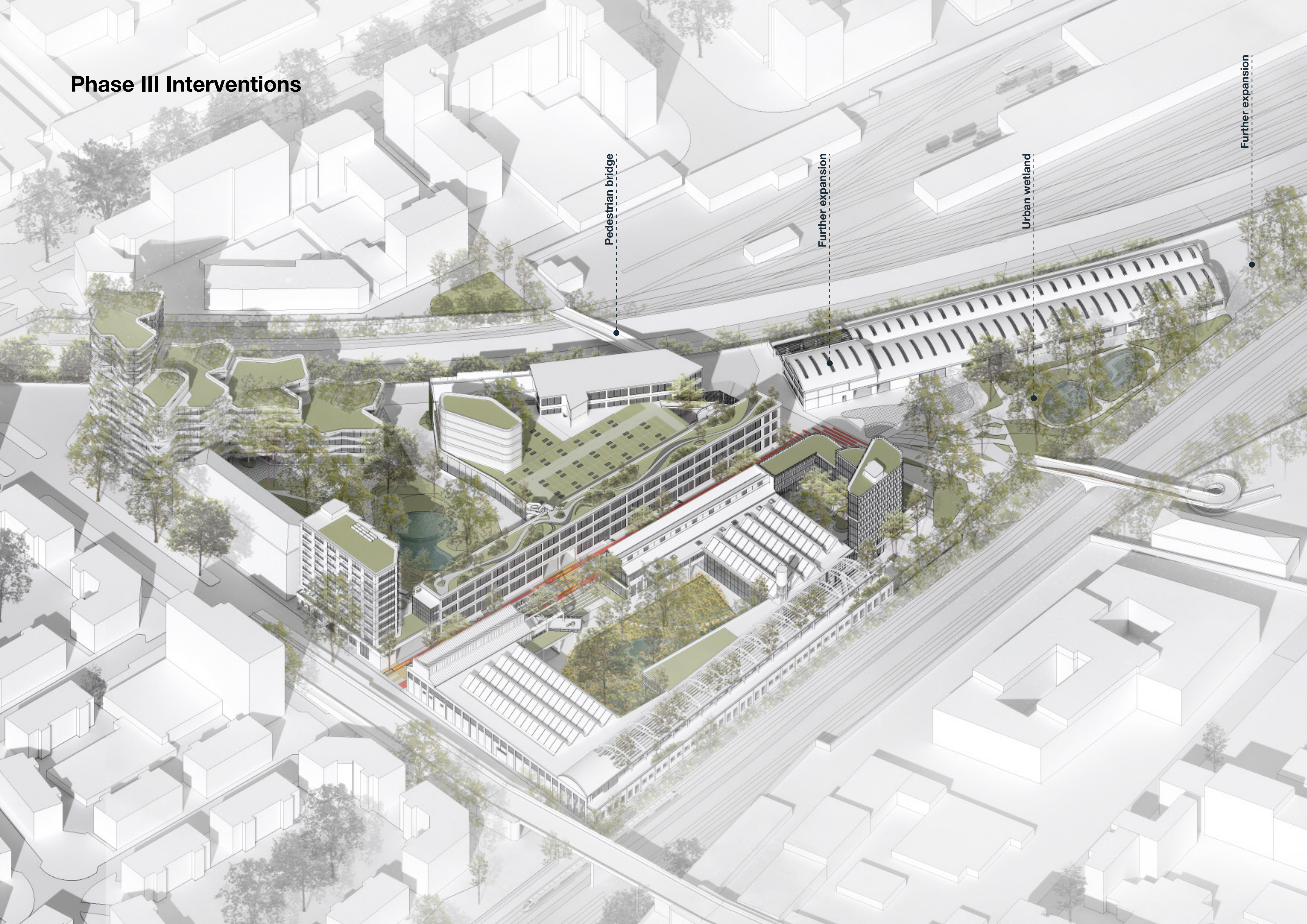
Production Cost	**16,686,514**
Works (CC)	12,299,883
Additional safety charges not to be discounted	245,998
Surveys, investigations and surveys + technical expenses design and construction supervision	1,254,588
Unexpected events	1,254,588
Acceptance of the works	125,459
VAT (value-added tax)	1,505,998

Investment cost	**31,246,434**
Production cost	16,686,514
Extraordinary maintenance	500,595
Loan Installment	14,059,325

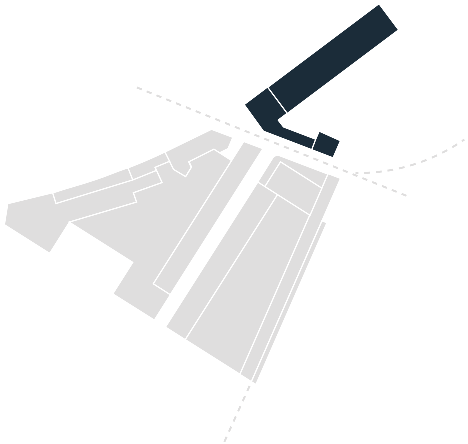
LEGEND

- ◯ *Primary Stakeholders*
- VP *Veto Players*
- △ *Secondary Stakeholders*

Phase III Interventions



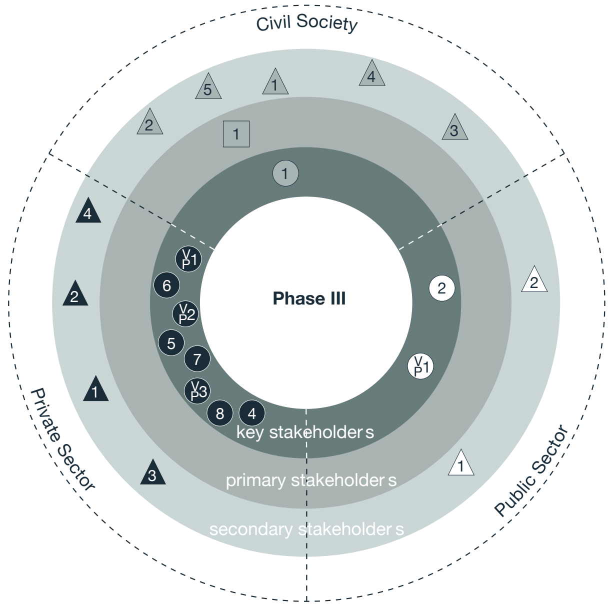
Potential Stakeholders of Phase III



VP1 - Societa Europa Risorce SRL
VP2 - Societa Montefelto SRL
VP3 - FS Sistemi Urbani
4 - Private Owner of Residential Building
5 - External investors
6 - Project developers
7 - Design team
8 - Construction team
▲1 - Gruppo Nova coop
▲2 - Biesse Investment SRL
▲3 - EDILCAM
▲4 - Local Businesses

VP1 - Municipality of Turin
2 - External investors
△1 - Universities in Turin
△2 - University of Turin

1 - External investors
1 - Communities
△1 - NGOs
△2 - Event organizers
△3 - Freelancers & employees
△4 - Students
△5 - Tourists



Existing functions	Type
Public square	Public
Urban wetland	Public
Pedestrian Bridge	Public
OSI East area:	
Plan A: Possible expansion of rooftop green house, [wine tasting, cellar, food, market],	Private/ Public
Plan B: Possible construction of high rise building [business, mixed use, research center, etc…]	
GHIA area:	
Possible expansion of Co-working/office	Private
Possible expansion of business/education	Private

Construction Cost (CC)	**3,728,078**

Production Cost	**5,057,659**
Works (CC)	3,728,078
Additional safety charges not to be discounted	74,562
Surveys, investigations and surveys + technical expenses design and construction supervision	380,264
Unexpected events	380,264
Acceptance of the works	38,026
VAT (value-added tax)	456,466

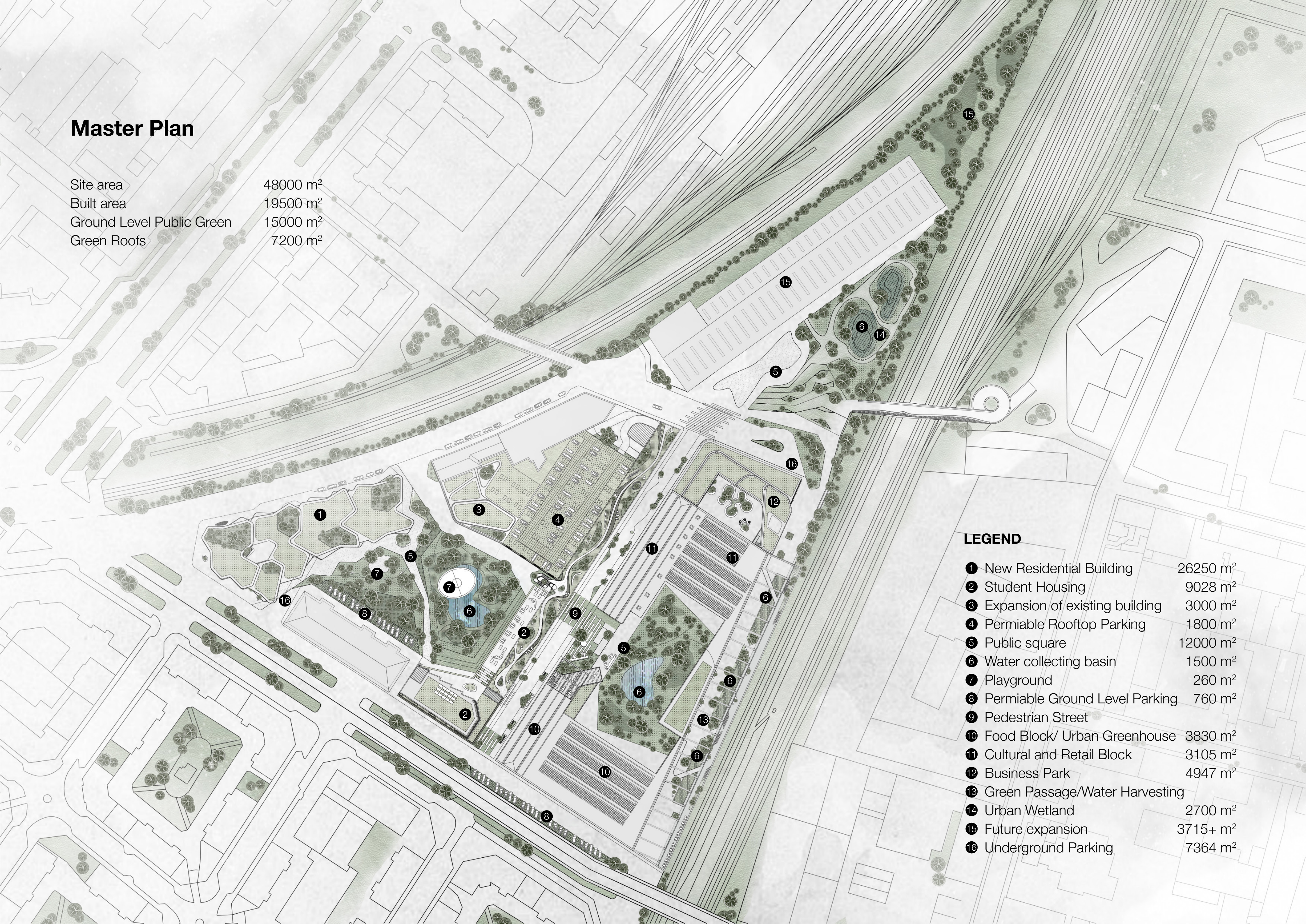
Investment cost	**19,268,714**
Production cost	5,057,659
Extraordinary maintenance	151,730
Loan Installment	14,059,325

LEGEND

○ *Primary Stakeholders*
VP *Veto Players*
△ *Secondary Stakeholders*

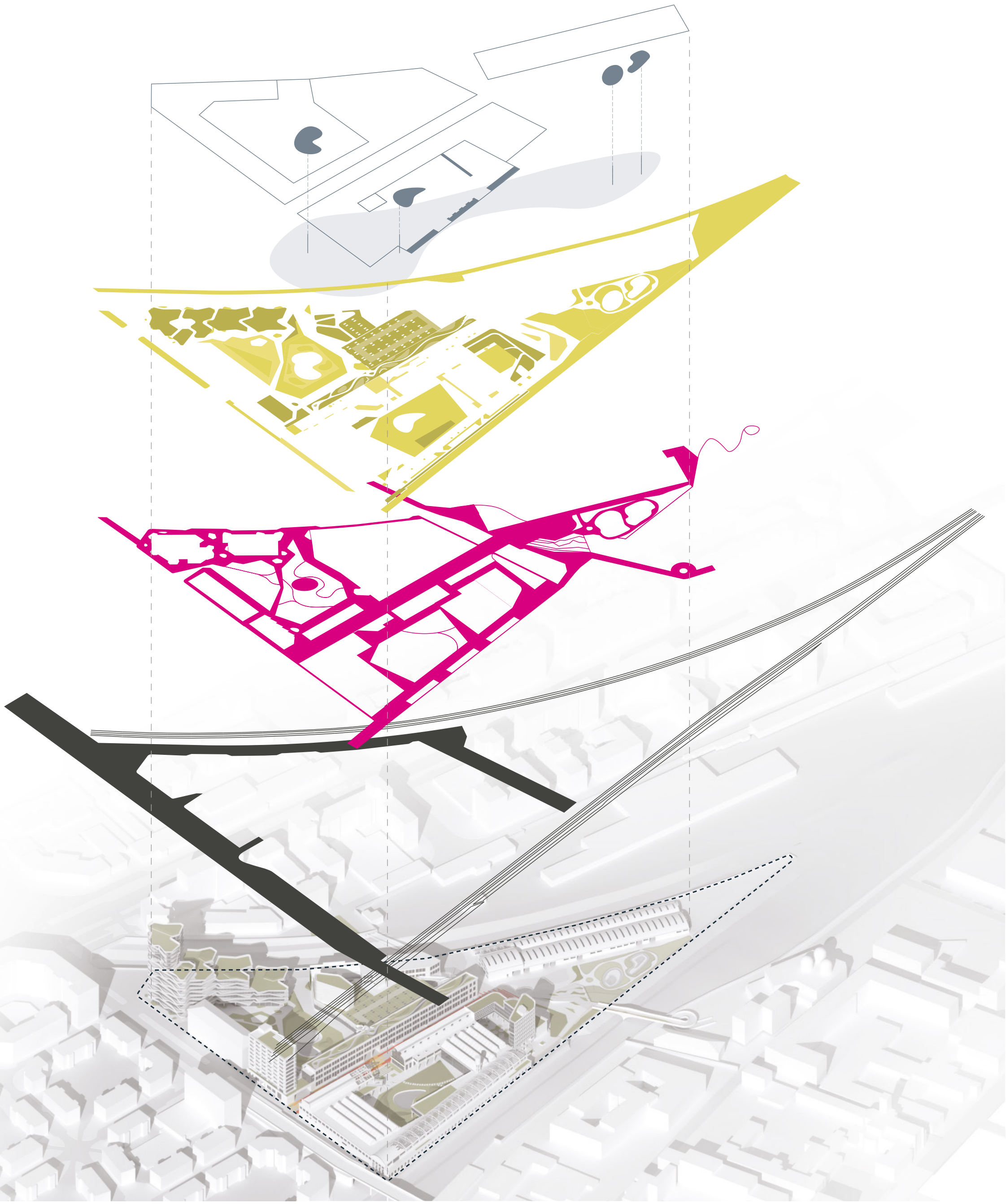
Master Plan

Site area	48000 m^2
Built area	19500 m^2
Ground Level Public Green	15000 m^2
Green Roofs	7200 m^2



LEGEND

1	New Residential Building	26250 m^2
2	Student Housing	9028 m^2
3	Expansion of existing building	3000 m^2
4	Permiable Rooftop Parking	1800 m^2
5	Public square	12000 m^2
6	Water collecting basin	1500 m^2
7	Playground	260 m^2
8	Permiable Ground Level Parking	760 m^2
9	Pedestrian Street	
10	Food Block/ Urban Greenhouse	3830 m^2
11	Cultural and Retail Block	3105 m^2
12	Business Park	4947 m^2
13	Green Passage/Water Harvesting	
14	Urban Wetland	2700 m^2
15	Future expansion	3715+ m^2
16	Underground Parking	7364 m^2



Rain Water Harvesting
Runoff water management and recycling, rain gardens and wetlands

Vegetation
Green roofs and ground level green spaces and corridors

Horizontal Pedestrian Flow
Principal and secondary links within the public spaces

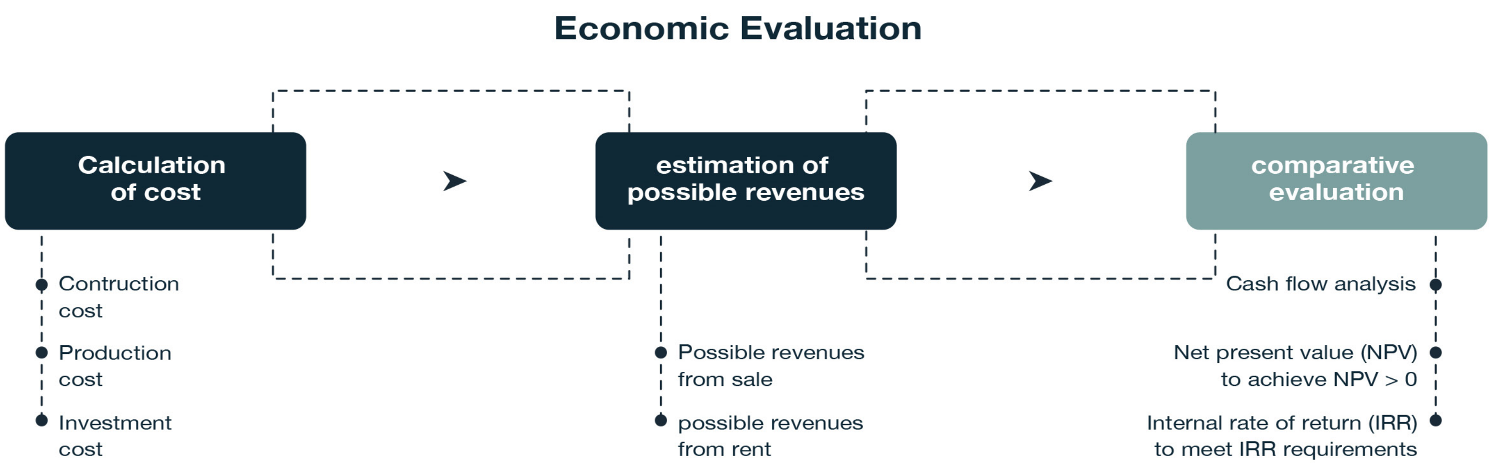
Vehicle Access and Barriers
Adjacent streets and the railway

Site Boundries
Former OSI Ghia industrial area in Turin

Ground Level Horizontal Pedestrian Flow

Economic evaluation
Cash flow analysis

Following the SWOT analysis as a conclusion for the site-related investigations, a stakeholders analysis has been conducted in order to identify the potential stakeholders and their power in the project development process. The project is developed in three phases referring to three portions of existing lots in the site, along with a preliminary phase related to design and paperwork. These are represented in a timeline specifying the works, their duration and sequence of realization in each phase. According to the timeline, the construction-related activities are estimated to be completed in 90 months, while for the phytoremediation procedure a longer period of time may be required.



Having the above mentioned development pattern, the economic evaluation has been carried out in three distinct phases, namely: calculation of costs, estimation of possible revenues and comparison of these two by applying a simplified cash flow analysis. The stakeholders analysis, functional distribution among phases and the costs related to each phase of construction are represented in separate diagrams accompanied by a 3D visualization of the projected interventions in the research.

Calculation of costs

This phase aims to calculate the investment cost for each construction phase which includes the production cost, the extraordinary maintenance (3% of production cost) and the loan installment.

The production cost is obtained by summing the construction cost (CC), additional safety charges, investigations and surveys, technical expenses,

FIGURE 76:
Table of possible revenue from sale

POSSIBLE REVENUE FROM SALE	
Sales Revenues	Revenue from sale [€]
New residential building	66,402,500
Food court	2,119,500
Rooftop green house	1,326,000
Cultural block	6,520,500
Office Building	13,512,300
Expansion of Green house	3,583,600
Adaptive reuse of the GHIA building	7,801,500
Possible revenue from sale [€]	**101,265,900**

POSSIBLE RENTAL REVENUES IN 15 YEARS				
Rental Revenues	Revenueof year 1 [€]	Revenue of year 2 [€]	Revenue of year 3 [€]	Revenue of year 4 [€]
GHIA area temporary use	245,190	490,380	490,380	490,380
Student housing			253728	507,456
New student housing				

FIGURE 77:
Table of total costs

Construction Cost (CC)	$ 60,895,809.70

Production Cost	$ 99,315,719.03
Works (CC)	$ 60,895,809.70
Additional safety charges not to be discounted	$ 1,217,916.19
Surveys, investigations and surveys + technical	$ 4,969,098.07
Unexpected events	$ 6,211,372.59
Acceptance of the works	$ 621,137.26
VAT (value-added tax)	$ 8,062,361.62
Loan (Interests)	$ 17,338,023.60

FIGURE 78:
Table of possible rental revenues in 15 years

design and construction supervision, unexpected events, acceptance of the works and value-added tax (VAT). While the construction cost is calculated by multiplying the quantity by the cost per unit of each work including those related to realization of public facilities(Annex,table 2). The costs per unit have been obtained through various references, handbooks and individual price analysis.

The loan conditions are developed within a 15 years

Revenue of year 5 [€]	Revenue of year 6 [€]	Revenue of year 7 [€]	Revenue of year 8 [€]	Revenue of year 9 [€]	Revenue of year 10 [€]	Revenue of year 11 [€]	Revenue of year 12 [€]	Revenue of year 13 [€]	Revenue of year 14 [€]	Revenue of year 15 [€]	Revenue in 15 years [€]
490,380	245190										2,451,900.00
507,456	507,456	507,456	507,456	507,456	507,456	507,456	507,456	507,456	507,456	507,456	6,343,200.00
1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	1,088,208	11,970,288.00
							Possible revenue from rentals in 15 years [€]				20,765,388.00

plan, considering the amount of loan equal to the total costs of all three phases, with a 2.5% interest rate included in the production costs(Annex,table 3).

Estimating the possible revenues

In this section the total possible revenues in 15 years have been calculated by summing the revenues from sales and rentals. For this purpose, firstly the hypothesis of considering the distinct portions of the project for rent or sale has been conducted. In this respect the student housing buildings are considered for rental and rest of the structures for sales revenues. Secondly, the price per unit analysis has been carried out by referring to various sources including "Geopoi" and individual inspections of similar case studies (Annex,table 4). Finally, the price per unit of each block is multiplied by the quantity in order to obtain the annual revenue for rentals (figure 78) and the total revenue for sales (figure 76). This amount is distributed in 15 years considering the project development timeline.

FIGURE 79:
Cash flow analysis

				5%	10%	20%	30%	20%	10%
				5%	5%	10%	10%	10%	10%
YEARS		1	2	3	4	5	6	7	8
Costs	I - II - III - Phase	$ -	$ -	$ 4,965,785.95	$ 9,931,571.90	$ 19,863,143.81	$ 29,794,715.71	$ 19,863,143.81	$ 9,931,571.90
Total (costs)		$ -	$ -	$ 4,965,785.95	$ 9,931,571.90	$ 19,863,143.81	$ 29,794,715.71	$ 19,863,143.81	$ 9,931,571.90
Revenues	Rent	$ 245,190.00	$ 490,380.00	$ 744,108.00	$ 997,836.00	$ 2,086,044.00	$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00
	Sales	$ -	$ -	$ 5,063,295.00	$ 5,063,295.00	$ 10,126,590.00	$ 10,126,590.00	$ 10,126,590.00	$ 10,126,590.00
Total (Revenues)		$ 245,190.00	$ 490,380.00	$ 5,807,403.00	$ 6,061,131.00	$ 12,212,634.00	$ 11,967,444.00	$ 11,967,444.00	$ 11,967,444.00
Cash Flow		$ 245,190.00	$ 490,380.00	$ 841,617.05	$ (3,870,440.90)	$ (7,650,509.81)	$ (17,827,271.71)	$ (7,895,699.81)	$ 2,035,872.10

NPV	19,180,123.34 €	
IRR	10.15%	> 9.2900%

5%

Comparision

The economic evaluation in this research aims to conduct a general simulation in order to verify the overall feasibility of the project. Therefore, in order to avoid any complexity, a simple cash flow analysis is carried out comparing the total production cost for all three construction phases with the total amount of the possible revenues in 15 years, with a varying percentage of costs and revenues in each period. The Net present value (NPV) is calculated considering 1.29% as the interest for a zero risk investment related to government bonds, in order to identify the annual income on the capital which is invested. The obtained value for NPV in this calculation is positive.

Meanwhile, the Internal rate of return (IRR) is compared with the sum of percentual related to no risk investment and the one related to all the risks (1.29%+8%), obtaining a positive result by having IRR=10.15% > 9.29% (figure 79).

5%						
10%	10%	10%	5%	5%	5%	5%
9	**10**	**11**	**12**	**13**	**14**	**15**
$ 4,965,785.95						
$ 4,965,785.95	$ -	$ -	$ -	$ -	$ -	$ -
$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00	$ 1,840,854.00
$ 10,126,590.00	$ 10,126,590.00	$ 10,126,590.00	$ 5,063,295.00	$ 5,063,295.00	$ 5,063,295.00	$ 5,063,295.00
$ 11,967,444.00	$ 11,967,444.00	$ 11,967,444.00	$ 6,904,149.00	$ 6,904,149.00	$ 6,904,149.00	$ 6,904,149.00
$ 7,001,658.05	$ 11,967,444.00	$ 11,967,444.00	$ 6,904,149.00	$ 6,904,149.00	$ 6,904,149.00	$ 6,904,149.00

Microclimatic assessment
Actual situation

As has been already mentioned in chapter 4, the microclimatic site-specific assessment has been developed for the research area before and after the implementation of NBS, Adaptation and mitigation strategies. This section discusses the actual microclimatic conditions of the site such as the potential air temperature, surface temperature, wind speed and predicted mean vote thermal comfort index utilizing the site-specific input data and various modules of the Envi-met software.

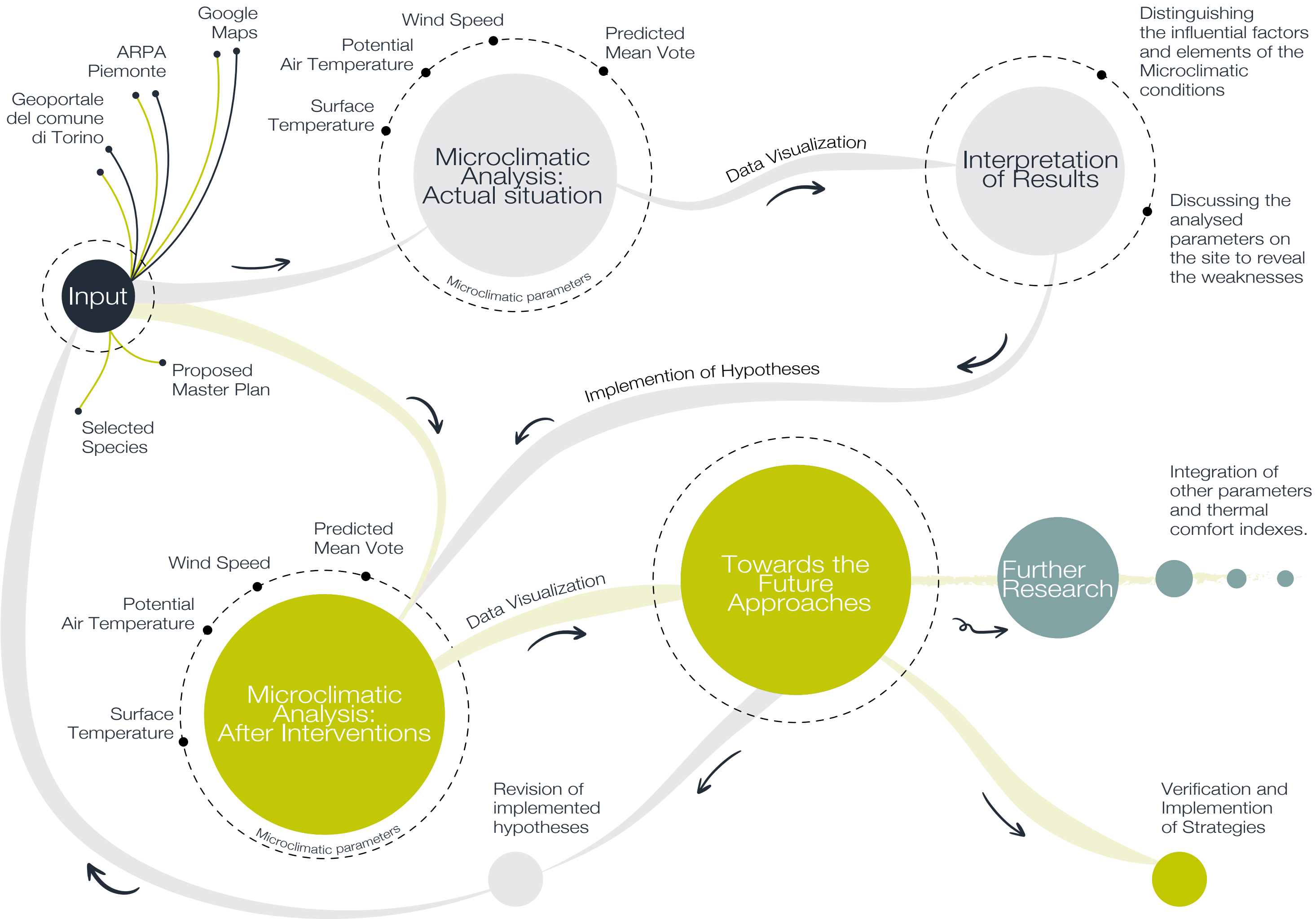
Input Data

It is of note that the input data have been defined and inserted not only in a single module of Envi-met but in various modules and phases of the entire process. To Begin, the 520x420 meters portion of the site has been extracted from carta tecnica of geoportale del comune di Torino to be used as a guiding plan to develop the modelling part in the spaces module. the selected area has been divided into 105x130 grids in the horizontal direction and 25 grids in the vertical direction along with 6 nesting grids in the boundaries of the site, so as to eliminate possible edge errors during the simulation phase. Besides a resolution of 4x4x3 has been chosen for this experiment.

Another step has been setting the location of the model up to the City of Turin by identifying its position on the earth with 45.07 degrees (+N,-S) latitude and 7.69 degrees (-W,+E) longitude, as well as specification of the time zone to Central European Standard Time and its reference longitude to 15.

Due to the nature of the research site refering the presence of the railways, it has been required to prepare a 5 meters high DEM level to distinguish the railways and the general ground level of site during the modeling process. The input data related to the public trees and their dimensions has been collected from the geoportale del comune di Torino according which the main applied species in the site are Pyrus calleryana, Platanus orientalis, Celtis australis. The next stage has been three-dimensional modeling of these trees in ALbero module, followed by their addition to the database after which they have been inserted in spaces module. However a very small fractions of trees have been detected only through

FIGURE 80:
Methodology of microclimatic assessment using the Envi-Met software.



LEGEND

- *Input data - actual situation*
- *Input data - implementation of hypotheses*

Material defined in Database Manager	Albedo	Emissivity	Material Applied in Spaces module
Asphalt Road (user edited)	0.1	0.95	Vehicle access and Parking Slots
Concrete Pavement Dark	0.2	0.90	Railways
Concrete Pavement Gray	0.5	0.90	Pedestrian acsess and sidewalks
Loamy Soil	0.0	0.98	Base layer of building and green areas
Grass 10 cm dense (user edited)	0.3	-	Grass covered surfaces

FIGURE 81:
Selection, Modification and application of materials using different modules of Envi-met

observation of the google map. Owing to the lack of access to spieces related data to modeling these trees, one of the Envi-met default options have been modified taking into account the features of the trees.The buildings heights are collected from the Geoportale del comune di Torino as well, while the collection of the data related to surface materials such as the grass covered surfaces, sidewalks and roads realised through google maps as reference source. The next step has been selecting these materials in database manager to apply in the spaces module. some materials has been modified manually in the database manager (figure 81).

Hour	T Air °C	R.H. %	Wind Velocity (m/s)	Wind Direction (°)
00:00 am	28.4	44	1.0	86
01:00 am	27.8	47	0.9	80
02:00 am	27.4	50	1.0	22
03:00 am	27.2	50	1.0	44
04:00 am	26.5	52	0.9	25
05:00 am	26.4	53	0.8	14
06:00 am	27.1	50	1.2	353
07:00 am	27.9	47	2.2	42
08:00 am	29.5	42	2.1	44
09:00 am	30.9	39	2.2	36
10:00 am	32.2	34	2.4	26
11:00 am	33.2	32	2.2	22
12:00 pm	34.5	29	0.5	230
13:00 pm	34.8	28	2.2	31
14:00 pm	35.4	29	3.2	66
15:00 pm	35.4	30	3.1	56
16:00 pm	34.8	30	3.1	60
17:00 pm	34.9	29	2.6	46
18:00 pm	34.0	29	3.2	47
19:00 pm	31.5	41	2.4	6
20:00 pm	30.5	45	1.8	36
21:00 pm	29.3	51	1.8	62
22:00 pm	28.1	57	1.8	86
23:00 pm	28.4	54	0.7	161

FIGURE 82:
Input Meteoroligal paremeters of 22-07-2022 gathered from Consolata station.

The successive stage of the process, has been setting up the simulation file in the Envi-met guide module. Consequently, the local meteorological data such as the Air temperature, wind direction, wind speed, relative humidity and global solar radiation have been gathered from ARPA meteorological station located on Via Della Consolata 10 (figure 82). The choice of station is due to its close distention to the research site as well as the availability of all required meteorological parameters in the station to be used during the analysis. The aim has been analyzing the microclimatic conditions on the hottest day of year taking into account the daily avarege air temparture. In this regard, simulation embraces the monitoring of microclimate during 48 hours starting from 22-07-2022 at 00:00 am. That's to say, the meteoroligal paremeters have been simulated for each hour starting from 00:00 am. The created simulation file has been loaded and run in Envi-met core module after an automatic checking process within the module to identify possible errors. the computing time required for the simulation was around 72 hours.

Output Data and visualisation

Simulation results include analysing the potential air temperature, surface temperature, wind velocity and PMV thermal comfort index. 09:00 am, 12:00 pm and 15:00 pm of 23-07-2022 have been taken as representative hours of the day. this choice tends to embrace also critical hot hours of the day such as 12:00 pm and 15:00 pm, so as to draw a comparison. except for the surface temperature, all other outputs are taken from 2.5 meters above ground level. Due to the converting principle of K value to the meters, and also considering the existence of a 5 meters high DEM layer, it was the closest altitude in respect to the average human height to be selected as a reference. The calculation of PMV thermal comfort index has been realised in the Bio-met module based on the atmosphere data of simulation and taking into account all possible K levels. As is already presented during this research, the Leonardo module of Envi-met is the platform which enables the visualisation of the simulation. each simulation in Envi-met consists of a vast range of data, which can be extracted in Leonardo, according to the direction of the study. For this research, the main data are extracted into Leonardo from the atmosphere and surface folders of the simulation defining the exact parameters such as wind speed, etc to demonstrate on certain K level.

Results: interpretation and overview

It is of crucial prominence to distinguish the indicating factors which have influenced the microclimatic conditions in order to deliver a detailed interpretation of the analysis. This section is a detailed discussion of all the factors and their impacts on the four parameters analysed during the microclimatic assesment.

Urban Morphology and Orientation

One of the main factors is urban morphology, referring to the forms of the urban fabric and its orientation (Erell et al., 2011). Perhaps Urban canyons such as via Bertini and via Montefeltro, as well as non-canyon (one-sided) urban space facing railways on the eastern and western sides (via Egeo) are the main present morphologies in the actual situation of the research site. The simulation of potential air temperature in chosen time periods of the day provides detailed information on air temperature in different urban forms presented on the site. A gradual ascend of temperature is registered on via Bertini, via Montefeltro, via Egeo and Corso Dante from 09:00 am to 15:00pm. However the temperature in these areas has been lower in all periods compared to the railways which has registered the highest air temperature, due to being a gnerally flat area and absence of shading edges. Overall, the air temperature along the entire via Bertini is around 30.86 °C, 32,94 °C, and 34 °C at 09:00 am, 12:pm and 15 pm respectively. the tempreture slightly increases in 15:00 pm At the junction of via Bertini and via Montefeltro as a result of changing the sun's position.The temperature on Via Montefeltro follows almost the same pattern as that of via Bertini. The exception is its very eastern part which intersects the railways being around 31.28 °C, 33.12 °C and 34.37 °C at 09:00 am, 12:00 pm and 15:00 pm respectively. This phenomenon is also visible in Corso Dante, where despite being one of the parts of the site with the lowest air temperature in all analysed periods especially on its western part and junction with via Egeo,it yet registers a higher temperature in the intersection with railways being 31.38 °C at 09:00 am, 33.65 °C at 12:00 pm and 34.53 at 15:00 pm. That is to say, these portions of the discussed streets are hotter than the rest of their part in all monitored periods. With regard to Via Egeo, while the temperature has been mainly similar to via Bertini and via Montefeltro in all periods yet its intersection with via Montefeltro registers slightly lower air temperature at 09:00 am which is related to the position of the sun and the presence of shaded zones only in specific parts as a result. Another Dynamic change in temperature occurs in the adjacent area of the Ghia Building. Compared to the other parts of the site this area is relatively more exposed to the sun at 09:00 am during which the temperature is around 31°C. later at 12:00 pm, the area benefits from the shades led by the urban form of the Ghia building. This applies also at 15:00 pm. Consequently, the portions close to Ghia building are experiencing a less rise in temperature than the other part in the immediate vicinity of railways.

As far as the wind speed and its direction are concerned, the wind flow corresponding to the analysis period is NE-SW. That's explaining the respective high wind speed in the adjacent open area next to Ghia Building. however, due to the presence of a multistory buildings on the opposite side of the railway, the speed decreases in the adjacent area to Osi East. Despite the obstacles due to surrounding buildings, the wind speed remains respectively high in the urban canyons via Bertini and via Montefeltro while It is reported the lowest in the courtyards.

Features of the urban surfaces

The compisition of the materials implemented on the urban surfaces should not be omitted from the assesment process, since this factor has a significant impact on the microclimatic conditions. (Battista et al., 2016, Marrone and Orsini, 2018). with this regard, the Albedo and emissivity of the materials are two characteristic to be considered.

FIGURE 83:

Potential air temperature for actual situation at k=6 (z=7.5 m)

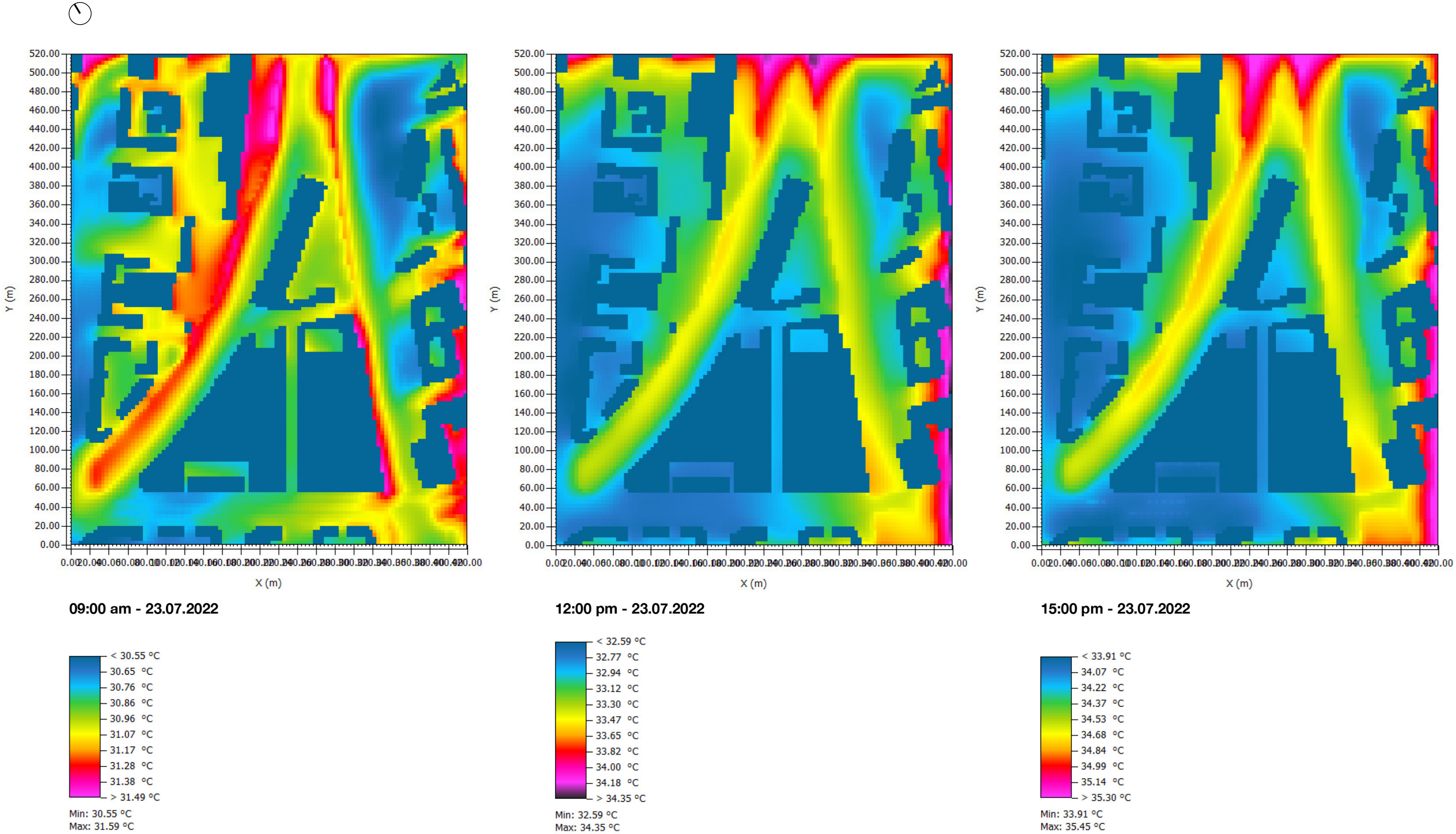
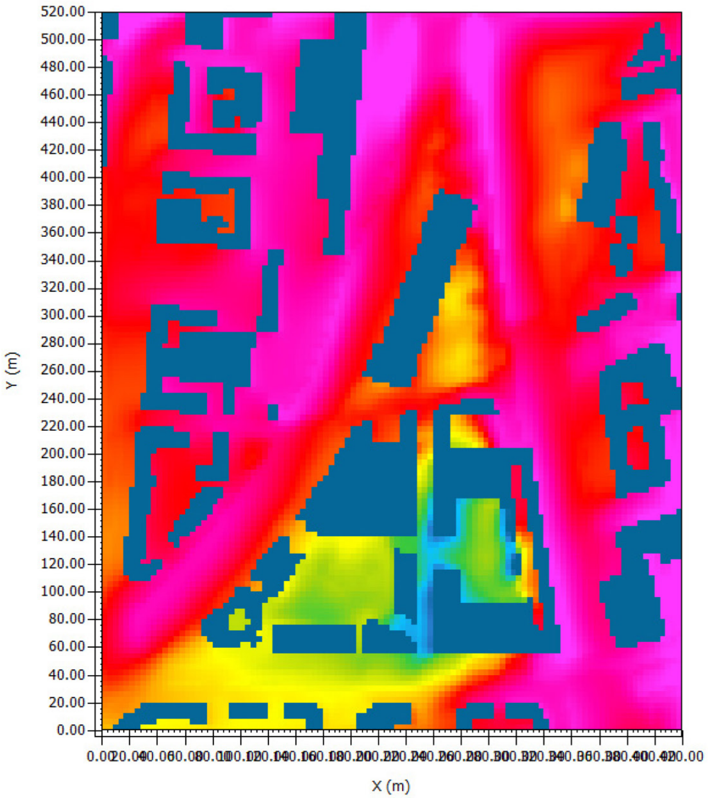


FIGURE 84:

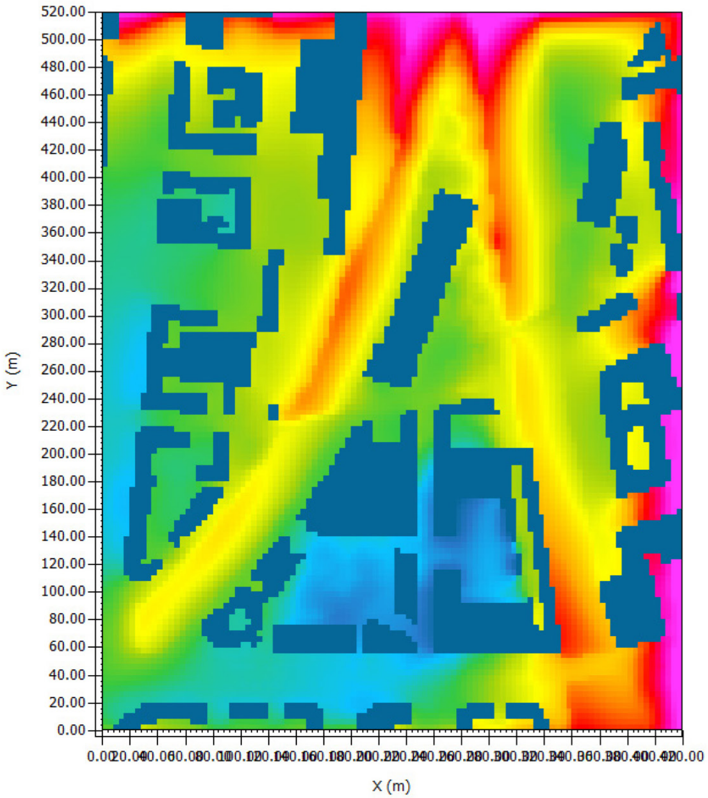
Potential air temperature after intervention at k=6 (z=7.5 m)



09:00 am - 23.07.2022

< 28.75 °C
29.02 °C
29.30 °C
29.57 °C
29.85 °C
30.13 °C
30.40 °C
30.68 °C
30.95 °C
> 31.23 °C

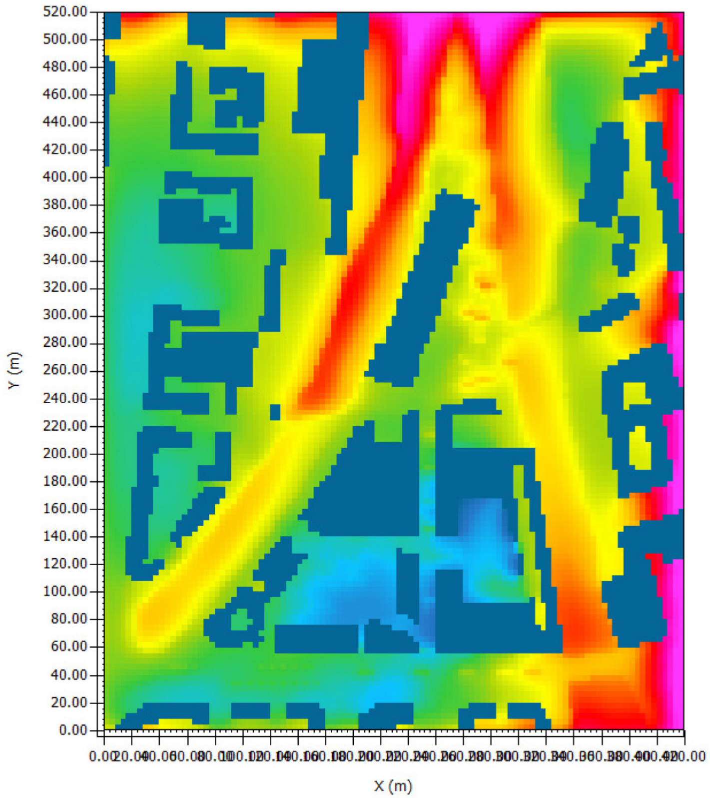
Min: 28.75 °C
Max: 31.51 °C



12:00 pm - 23.07.2022

< 32.10 °C
32.32 °C
32.54 °C
32.76 °C
32.97 °C
33.19 °C
33.41 °C
33.63 °C
33.85 °C
> 34.07 °C

Min: 32.10 °C
Max: 34.28 °C

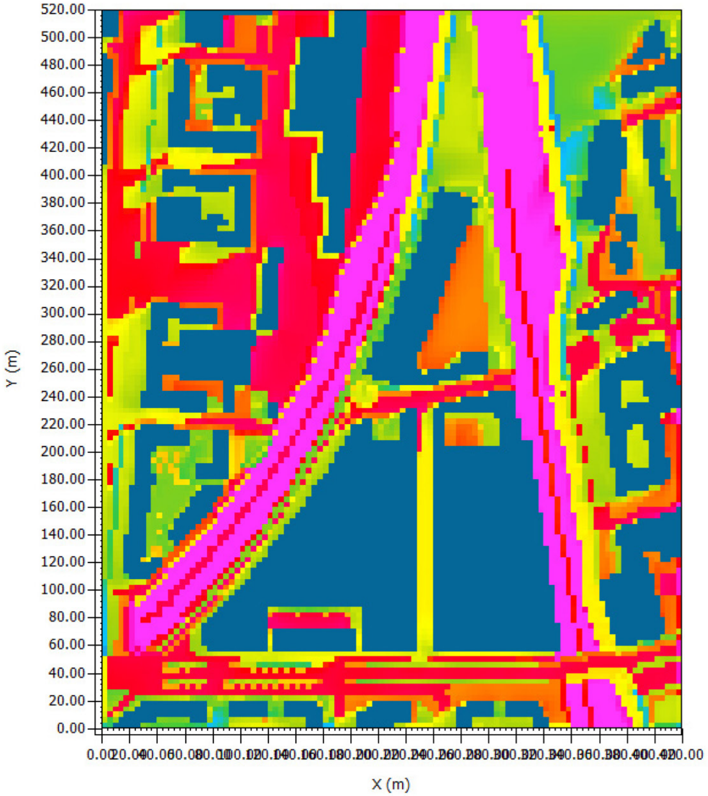


15:00 pm - 23.07.2022

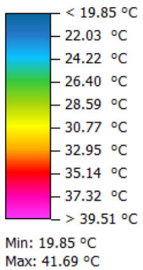
< 33.39 °C
33.59 °C
33.79 °C
33.99 °C
34.19 °C
34.39 °C
34.59 °C
34.79 °C
34.99 °C
> 35.19 °C

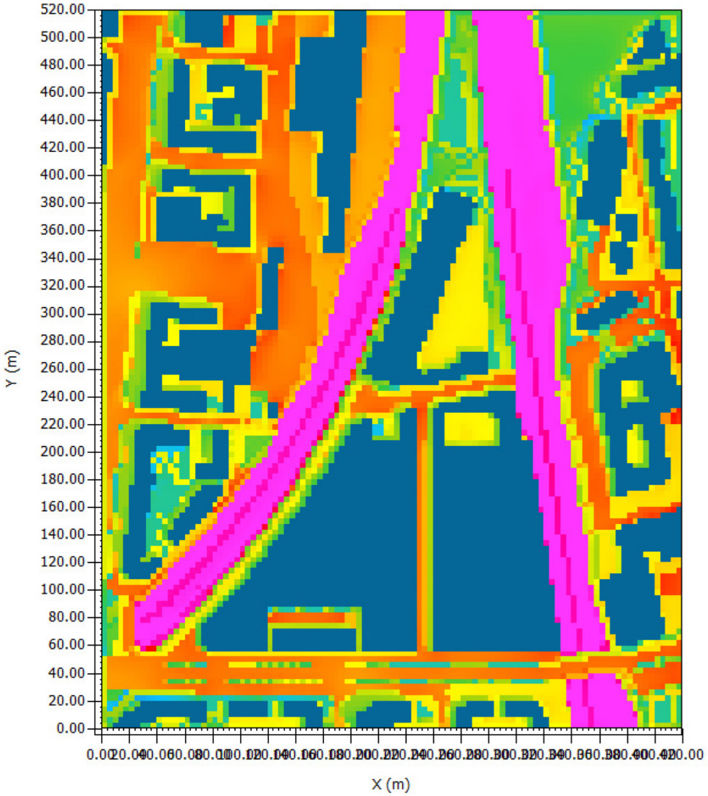
Min: 33.39 °C
Max: 35.39 °C

FIGURE 85:
Surface temperature for actual situation at k=0 (z=0.0 m)

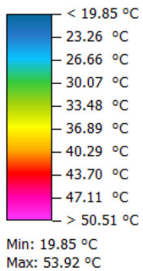


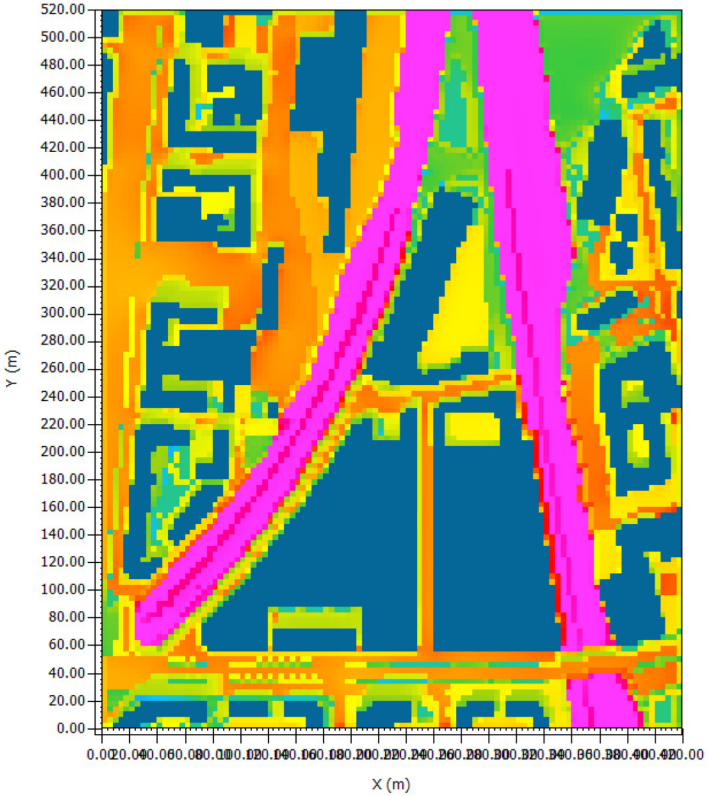
09:00 am - 23.07.2022





12:00 pm - 23.07.2022





15:00 pm - 23.07.2022

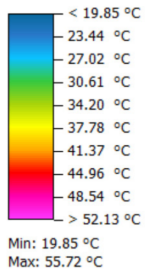
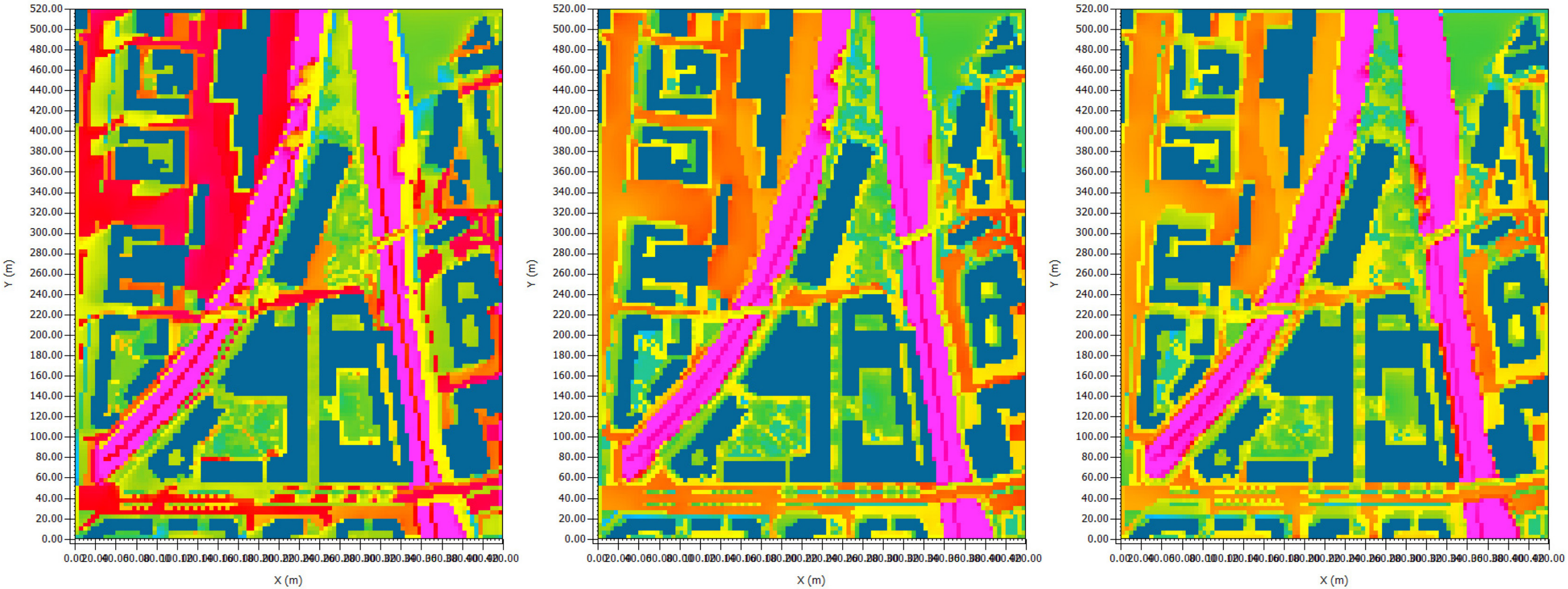


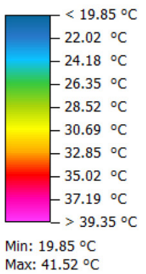
FIGURE 86:
Surface temperature after intervention at k=0 (z=0.0 m)

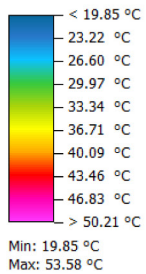


09:00 am - 23.07.2022

12:00 pm - 23.07.2022

15:00 pm - 23.07.2022





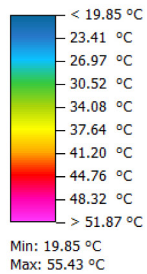
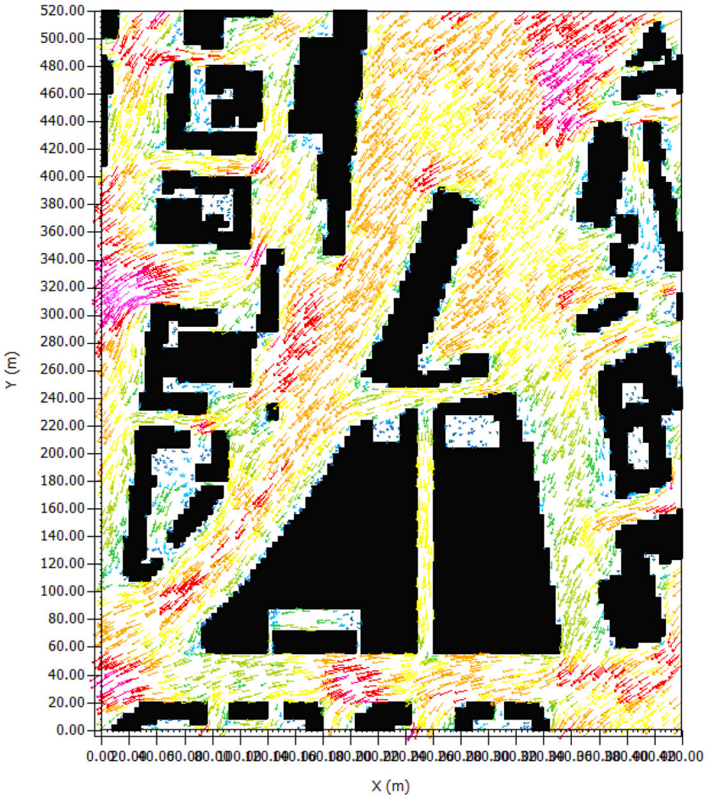


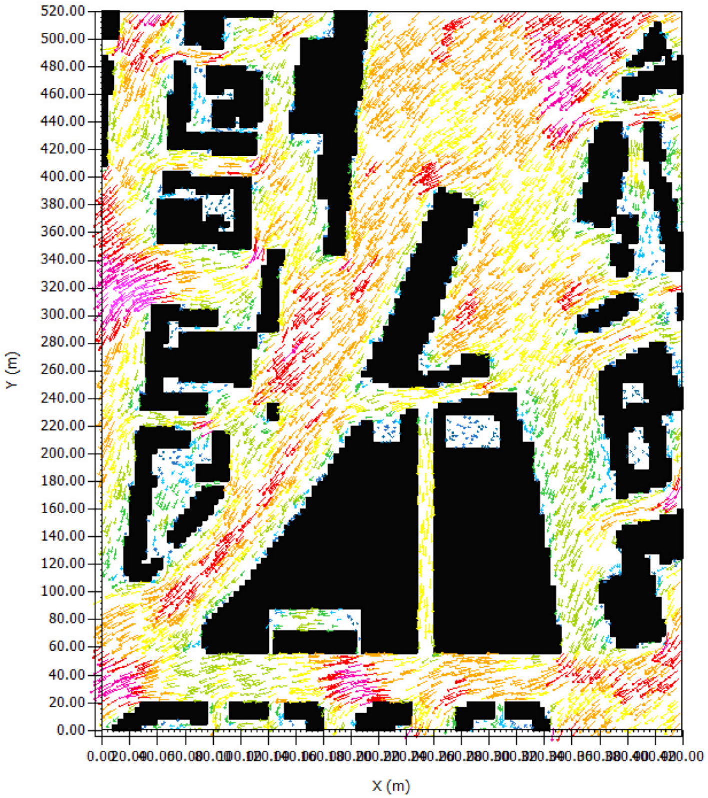
FIGURE 87:
Wind speed for actual situation at k=6 (z=7.5 m)



09:00 am - 23.07.2022

- below 0.14 m/s
- 0.14 to 0.28 m/s
- 0.28 to 0.42 m/s
- 0.42 to 0.56 m/s
- 0.56 to 0.70 m/s
- 0.70 to 0.84 m/s
- 0.84 to 0.98 m/s
- 0.98 to 1.11 m/s
- 1.11 to 1.25 m/s
- above 1.25 m/s

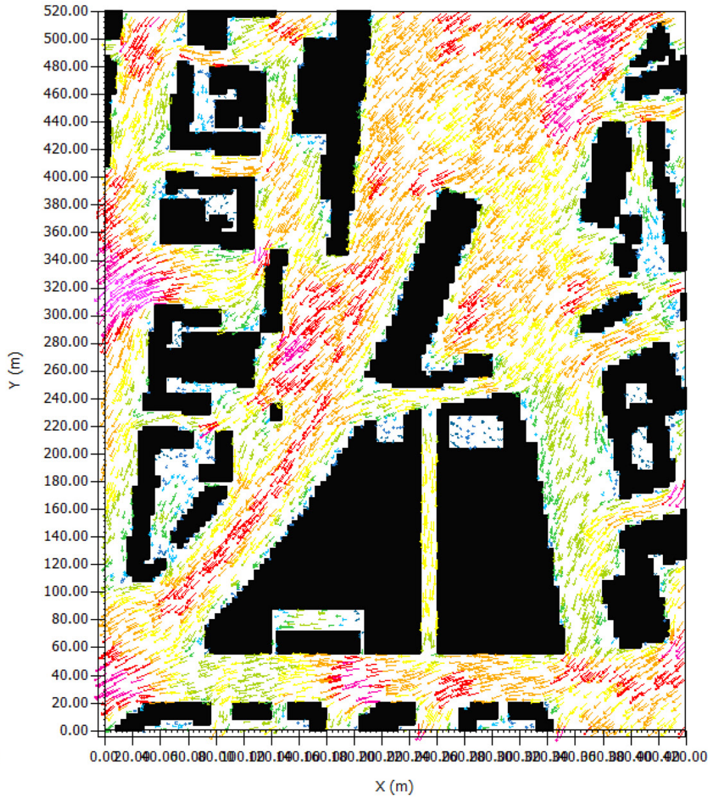
Min: 0.00 m/s
Max: 1.39 m/s



12:00 pm - 23.07.2022

- below 0.14 m/s
- 0.14 to 0.27 m/s
- 0.27 to 0.41 m/s
- 0.41 to 0.54 m/s
- 0.54 to 0.67 m/s
- 0.67 to 0.81 m/s
- 0.81 to 0.94 m/s
- 0.94 to 1.08 m/s
- 1.08 to 1.21 m/s
- above 1.21 m/s

Min: 0.00 m/s
Max: 1.35 m/s



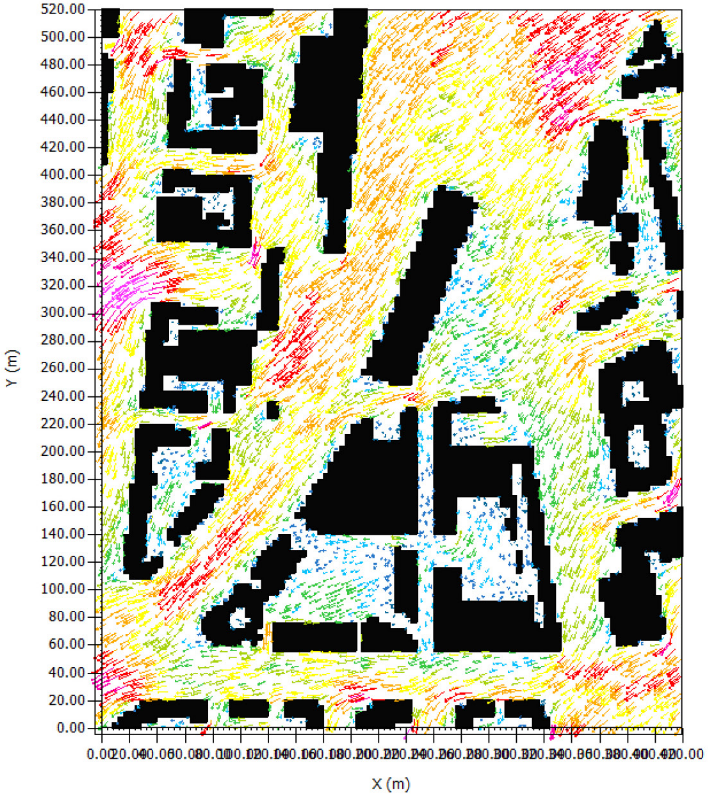
15:00 pm - 23.07.2022

- below 0.13 m/s
- 0.13 to 0.26 m/s
- 0.26 to 0.39 m/s
- 0.39 to 0.53 m/s
- 0.53 to 0.66 m/s
- 0.66 to 0.79 m/s
- 0.79 to 0.92 m/s
- 0.92 to 1.05 m/s
- 1.05 to 1.18 m/s
- above 1.18 m/s

Min: 0.00 m/s
Max: 1.31 m/s

FIGURE 88:

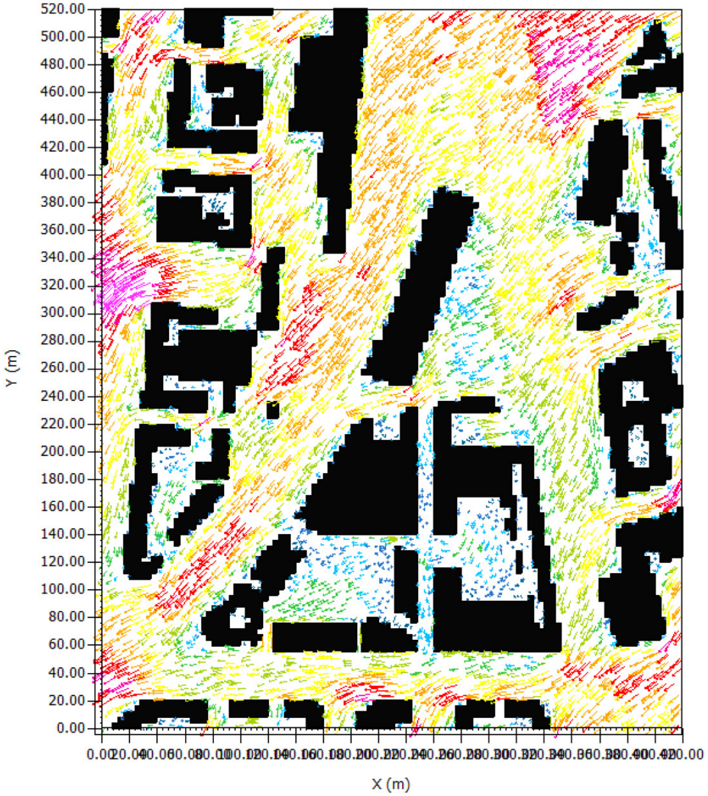
Wind speed after intervention at k=6 (z=7.5 m)



09:00 am - 23.07.2022

- below 0.14 m/s
- 0.14 to 0.28 m/s
- 0.28 to 0.42 m/s
- 0.42 to 0.56 m/s
- 0.56 to 0.70 m/s
- 0.70 to 0.84 m/s
- 0.84 to 0.98 m/s
- 0.98 to 1.12 m/s
- 1.12 to 1.25 m/s
- above 1.25 m/s

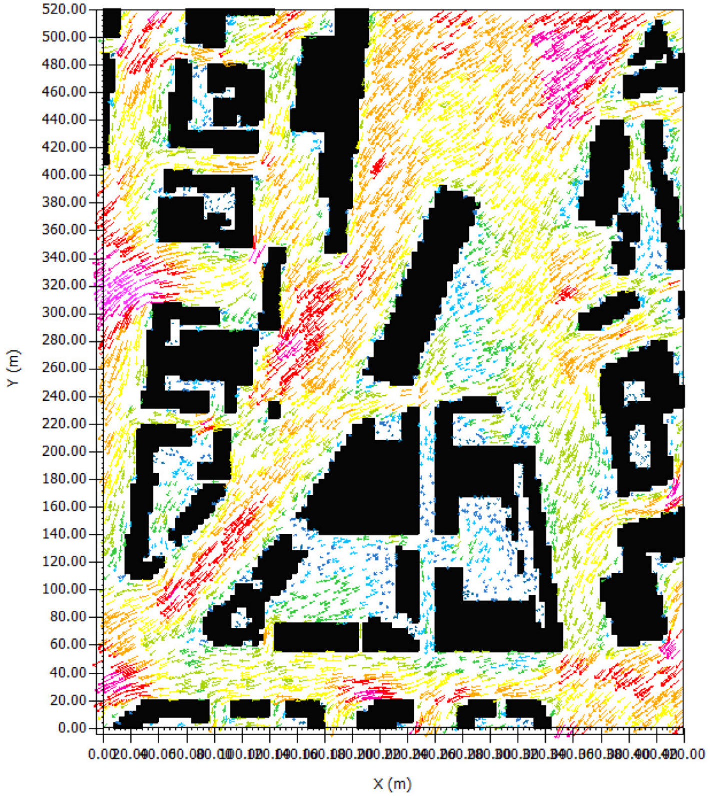
Min: 0.00 m/s
Max: 1.39 m/s



12:00 pm - 23.07.2022

- below 0.14 m/s
- 0.14 to 0.27 m/s
- 0.27 to 0.41 m/s
- 0.41 to 0.54 m/s
- 0.54 to 0.68 m/s
- 0.68 to 0.81 m/s
- 0.81 to 0.95 m/s
- 0.95 to 1.08 m/s
- 1.08 to 1.22 m/s
- above 1.22 m/s

Min: 0.00 m/s
Max: 1.35 m/s



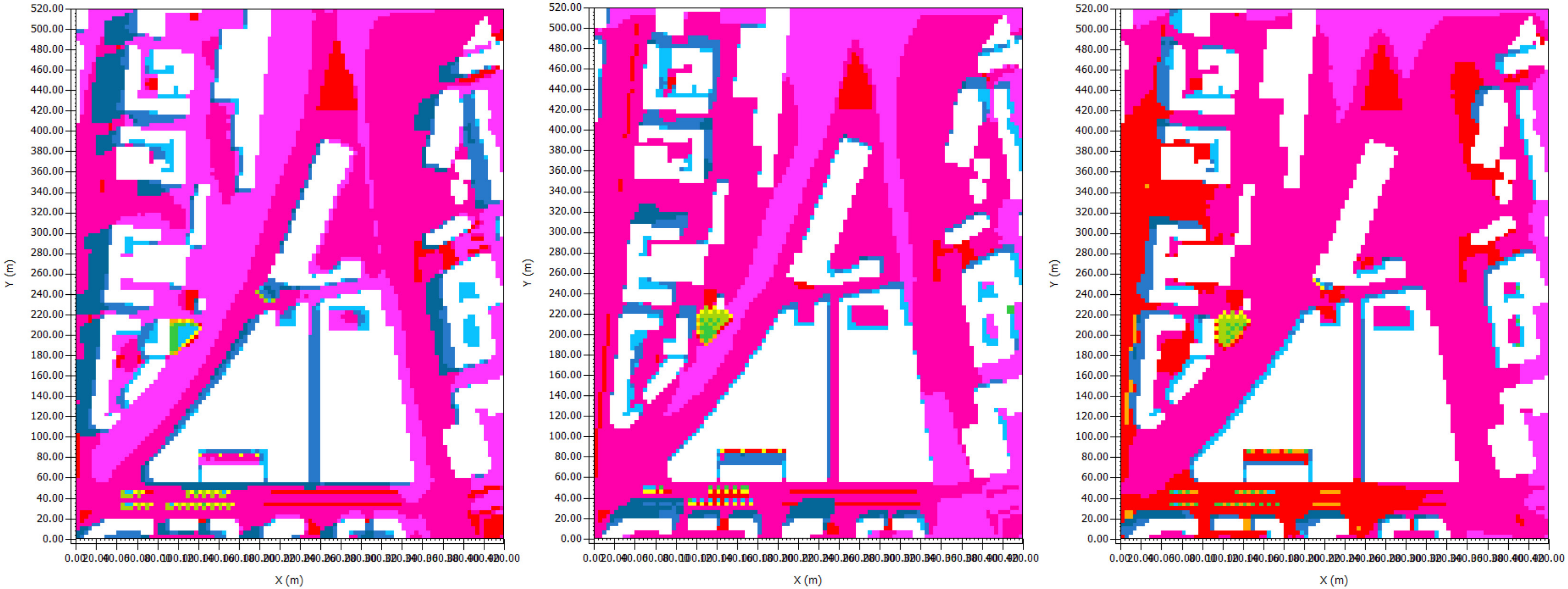
15:00 pm - 23.07.2022

- below 0.13 m/s
- 0.13 to 0.26 m/s
- 0.26 to 0.39 m/s
- 0.39 to 0.53 m/s
- 0.53 to 0.66 m/s
- 0.66 to 0.79 m/s
- 0.79 to 0.92 m/s
- 0.92 to 1.05 m/s
- 1.05 to 1.18 m/s
- above 1.18 m/s

Min: 0.00 m/s
Max: 1.31 m/s

FIGURE 89:

Predicted mean vote for actual situation at k=6 (z=7.5 m)



09:00 am - 23.07.2022

PMV

- below 2.40
- 2.40 to 2.59
- 2.59 to 2.77
- 2.77 to 2.96
- 2.96 to 3.15
- 3.15 to 3.33
- 3.33 to 3.52
- 3.52 to 3.71
- 3.71 to 3.89
- above 3.89

Min: 2.21
Max: 4.08

12:00 pm - 23.07.2022

PMV

- below 3.29
- 3.29 to 3.45
- 3.45 to 3.60
- 3.60 to 3.75
- 3.75 to 3.91
- 3.91 to 4.06
- 4.06 to 4.22
- 4.22 to 4.37
- 4.37 to 4.52
- above 4.52

Min: 3.14
Max: 4.68

15:00 pm - 23.07.2022

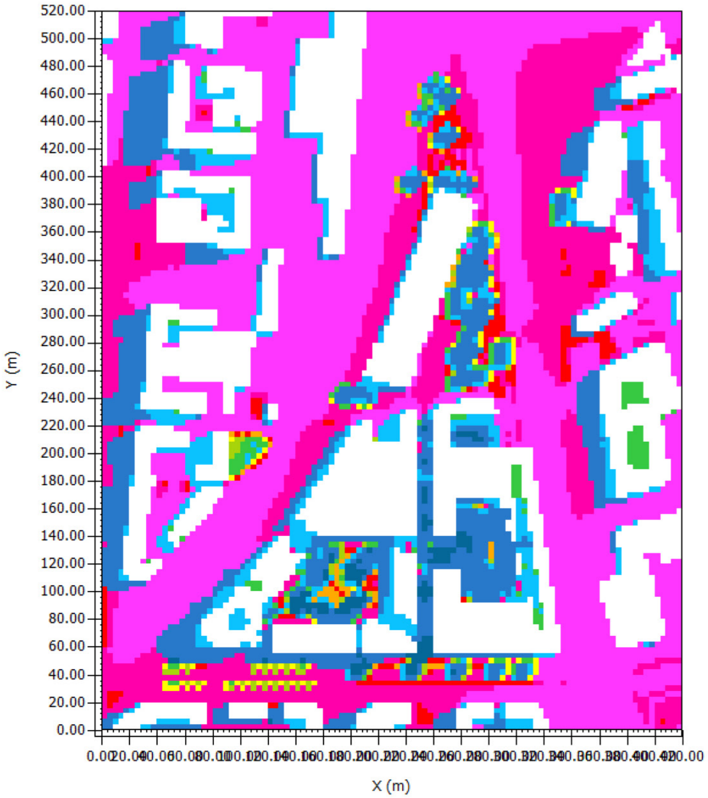
PMV

- below 3.52
- 3.52 to 3.70
- 3.70 to 3.88
- 3.88 to 4.06
- 4.06 to 4.23
- 4.23 to 4.41
- 4.41 to 4.59
- 4.59 to 4.77
- 4.77 to 4.94
- above 4.94

Min: 3.35
Max: 5.12

FIGURE 90:

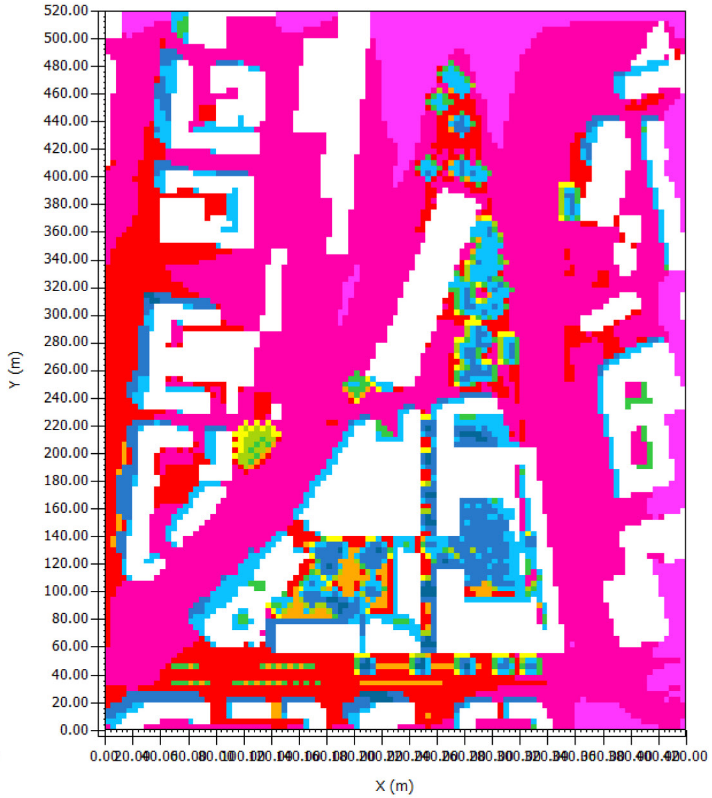
Predicted mean vote after intervention at k=6 (z=7.5 m)



09:00 am - 23.07.2022

- below 2.09
- 2.09 to 2.30
- 2.30 to 2.51
- 2.51 to 2.73
- 2.73 to 2.94
- 2.94 to 3.15
- 3.15 to 3.36
- 3.36 to 3.57
- 3.57 to 3.78
- above 3.78

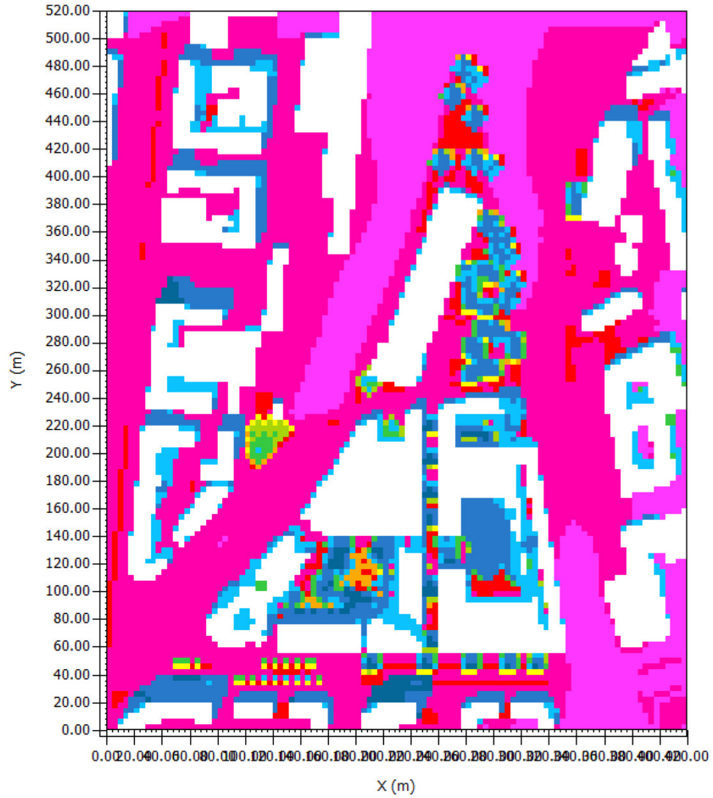
Min: 1.88
Max: 3.99



12:00 pm - 23.07.2022

- below 3.06
- 3.06 to 3.23
- 3.23 to 3.41
- 3.41 to 3.58
- 3.58 to 3.75
- 3.75 to 3.93
- 3.93 to 4.10
- 4.10 to 4.28
- 4.28 to 4.45
- above 4.45

Min: 2.89
Max: 4.62



15:00 pm - 23.07.2022

- below 3.31
- 3.31 to 3.51
- 3.51 to 3.70
- 3.70 to 3.90
- 3.90 to 4.09
- 4.09 to 4.29
- 4.29 to 4.48
- 4.48 to 4.68
- 4.68 to 4.87
- above 4.87

Min: 3.12
Max: 5.07

The main ingredients of the material composition of the research site are already introduced in the input data section of this research. It is evident that a subtantial portion of the site is covered by Asphalt which has a very low albedo and high emissivity. Cosequently, it tends to absorb a substantial amount of the total solar radiation that it gains. That is to say, a partial transformation of the gained solar radiation to heat energy is expected. Another critical material is the concrete pavement dark which is applied on the railways. On the other hand, the surface temprature related to sidewalks covered with concrete pavement gray is substantially lower due to it higher albedo and emissivity in respect to the asphalt.

Vegetation

Considering the microclimating condition, there are certain impacts led by the presence of the vegation in the urban area. these effects are not limited only to experiencing lower potential air temprature and enhancment of the thermal comfort in the area of their implementation, but also bringing perceptible benefits to the human health and well-being. (World Bank, 2021, Battista et al., 2016, Marrone and Orsini, 2018). Noticeably the grass covered as well as tree planted areas have registered a significantly lower surface temprature than the other materials in all selected chosen periods. Regarding the potential air tempreture, the effects of vegetation is more perceptible in the tree planted areas than grass covered areas. However, the results of the PMV in all selected periods, proves that also the grass covered areas have more favourable value along with the tree planted areas regardless if planted following a linear path or as a group. The trees on Corso Dante and the group of trees on via Jonio are some brilliant illustrations to the point.

Conclusion:

The discussion of analysed parameters by effective factors is a useful method to reveal the weaknesses to develop intervention strategies accordingly. Analysis of the potential air temperature, surface temperature, wind speed and PMV of the site are represented in the figure 83, 85, 87 and 89. respectively.

Microclimatic assessment
Implementation of NBS

The second analysis aims to assess the implementation of the NBS and adaptation strategies.The same meteorological parameters have been assessed during the analysis.

Input Data

In this case a 520x420 meters portion of the proposed and developed masterplan has been aligned with the previously used image extracted from carta tecnica of geoportale del comune di Torino to be used as the guiding map in the spaces module. in other words, the image from carta tecnica has been replaced by the image from master plan with an accurate alignment of images.The resolution, number of the grids and nesting grids as well as the location, time zone and previously defined DEM layer remained the same being consistent with the first analysis data. A partial modification of the site has been carried out by adding or eliminating some elements according to the new master plan. As far as the vegetations are concerned, new species of trees has been chosen and defined in the Albero module following the same principal done for the first analysis. the detailed data related to the selected trees are provided later in this chapter. Moreover, green roofs and green walls have been applied to some existing and proposed buildings. In addition to the materials which had been already chosen and defined in the previous simulation, sand soil with the Albedo 0.25 and emissivity 0.98, wood planks with the albedo 0.5 and emissivity 0.9 have been used in playgrounds and wooden decks respectively. The analysis has been held for the hottest day of year which is presenting the dry season. Consequently, the nature-based solution have not been calculated with their total potential of the effect on the site. For instance, the proposed wetlands and other water harvesting basins which in fact would affect the PMV, potential air temperature and surface temperature have not been consider as water surfaces.
Regarding the simulation, the same meteorological data have been used, in order to draw an accurate comparison. Simulation includes the analysis of microclimatic conditions in 48 hours beginning from 22-07-2022 at 00:00 am as it was in first simulation.

Output Data and visualisation

Simulation results embrace the analysis of the same meteorological parameters following similar selected representative hours of the day and principles of the choices made which are presented in the previous analysis. Regarding PMV , the atmosphere data have been gathered by the bio-met module, using the new output to be accordingly visualized in the Leonardo module.

Results: Towards the future approaches

While the first simulation acted as a catalyst to reveal the influential factors and elements on the microclimatic conditions of the research site to come up with efficient hypotheses, the output of the second simulation, shed light on the feasible directions of future approaches which are presented in this section.

Verification and Implemention of strategies

Integration of more vegetated areas as well as considering possible transformations of the urban forms, along with the replacement of high albedo materials such as asphalt with low albedo material for the proposed pedestrian paths are some brilliant illustrations to demonstrate the amelioration of the thermal comfort, potential air temperature, and regulating the airflow in proposed zones. The comparison with the actual situation has led to the verification or revision of hypotheses to select the definitive NBS, adaptation and mitigation strategies. Analysis of the potential air temperature, surface temperature, wind speed and PMV of the proposal are represented in the figure 84, 86, 88 and 90 respectively.

Future expansions of the assessing parameters

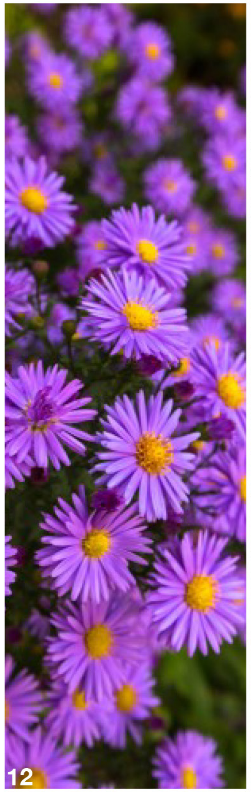
However, the assessment of the four parameters can be considered a crucial milestone in the development of strategies, further research still remains open for the analysis of air pollution sources which regularly affect the microclimate of the site. Moreover, the study of other thermal comfort indexes such as the PET and UTCI would be useful to reach more quantitative thermal comfort values.

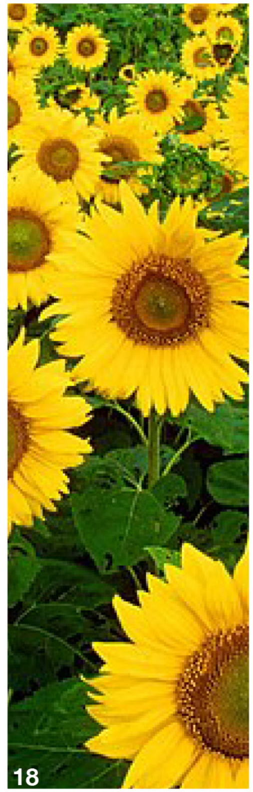
Selection of Plant Species

The tools and aspects introduced in chapter four of the research such as the phytoremediation and attraction of biodiversity along with the results of the microclimatic analysis of the site are revealing the prominence of a proper selection of the species to be applied in the research site, in order to reach more efficient interventions.
The plant choices and their position in the research site have been feasible by considering various criteria which are presented in figure 91.
Definitely, the habitat of the plants has been taken into account to ensure their adaptivity to deal with microclimatic conditions including their water demand, and their resisting ability against various extreme climatic conditions such as drought, wind, flood and frost. A crucial milestone has been the purpose definition of their application. Species with a high ability to extract hazadous metals can act more efficiently if implemented in the contaminated parts of the site. Moreover, this effect could be even more tangible in a certain time span in case of considering the growth rate of chosen plants. Another target has been selecting species which tend to attract biodiversity such as various polinators, bees, butterflies and birds. This feature is also evident in many of the selected plants with the primary purpose of phytoremediation. Ultimately, a picturesque palette of varying colours throughout the year is applied in order to fulfils the various aspects of Biophilia.
The dimensions and other physical characteristics are also fundamental criteria to be considered. As it is discussed in this chapter, the thermal comfort, potential air temperature, and airflow of the site can be significantly affected due to the vegetation.

FIGURE 91:
Selection of plant species

PLANT	TYPE	GROWTH/Year	DIMENSIONS	WATER DEMAND	TARGET	HABITAT	COMMENTS	COLOR: Spring I SummerI AutumnI Winter
1.Tilia cordata	Tree	30-60 cm	H=12-22 m	Drought tolerant Suitable for any soil	Phytoremediation bees, butterflies	Europe	Wind/ frost resistant Not toxic	
2. Ulmus laevis	Tree	40-50 cm	H=30-35 m	Prefers water but is also drought tolerant	Phytoremediation bees, butterflies	Europe	Flood/ frost resistant Not toxic	
3. Acer platanoides	Tree	15 cm	H=20-30 m	Prefers water but is also drought tolerant	Phytoremediation bees, butterflies	Europe, West Asia	Flood/ frost resistant Toxic components	
4. Prunus padus	Tree	20-40 cm	H=8-15 m	Average water need prefers drained soil	Bees, butterflies, food for birds	Europe	Wind/ flood resistant Not toxic	
5. Magnolia Kobus	Tree	20-30	H=8-12 m	prefers drained soil & water in drought	Pollinators, beetles, birds	Origin:Japan Italy included	Wind/ flood / frost resistant, Not toxic	
6. Nyssa sylvatica	Tree	30-60 cm	H=15-25 m	Average wet soil also drought tolerant	Bees, food for birds	Origin:America Italy included	Moderate wind/ frost resistant, Not toxic	
7. Populus nigra Italica	Tree	90 cm	H=15-20 m	Well drained soil also drought tolerant	Phytoremediation butterflies	Origin: Northern Italy	Flood / frost resistant, Not toxic	
8. Salix Alba	Tree	300 cm	H=20-35 m	Suitable for wet soil flood resistant	Phytoremediation bees, butterflies	Europe, Asia, North Africa	Wind/ flood / frost resistant, Not toxic	
9. Cornus Alba Sibirica	Shrub	40-60 cm	H<1.5 m	Drought tolerant Low water demand	Phytoremediation bees, birds	Siberia,China, Italy included	Not toxic	

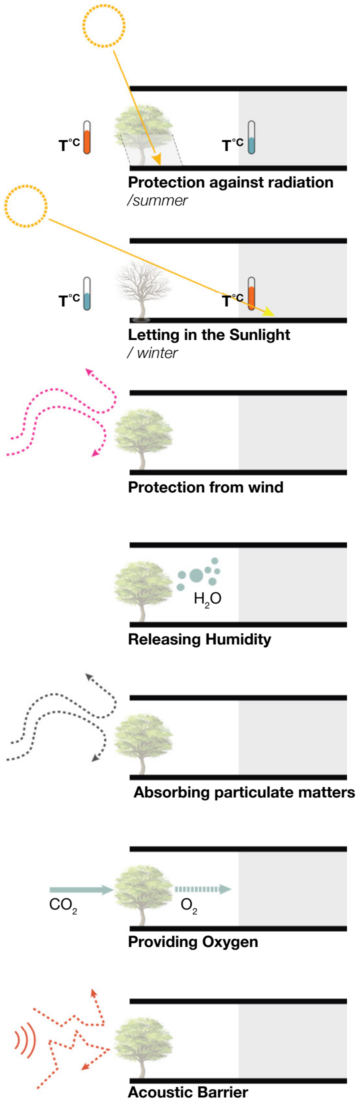


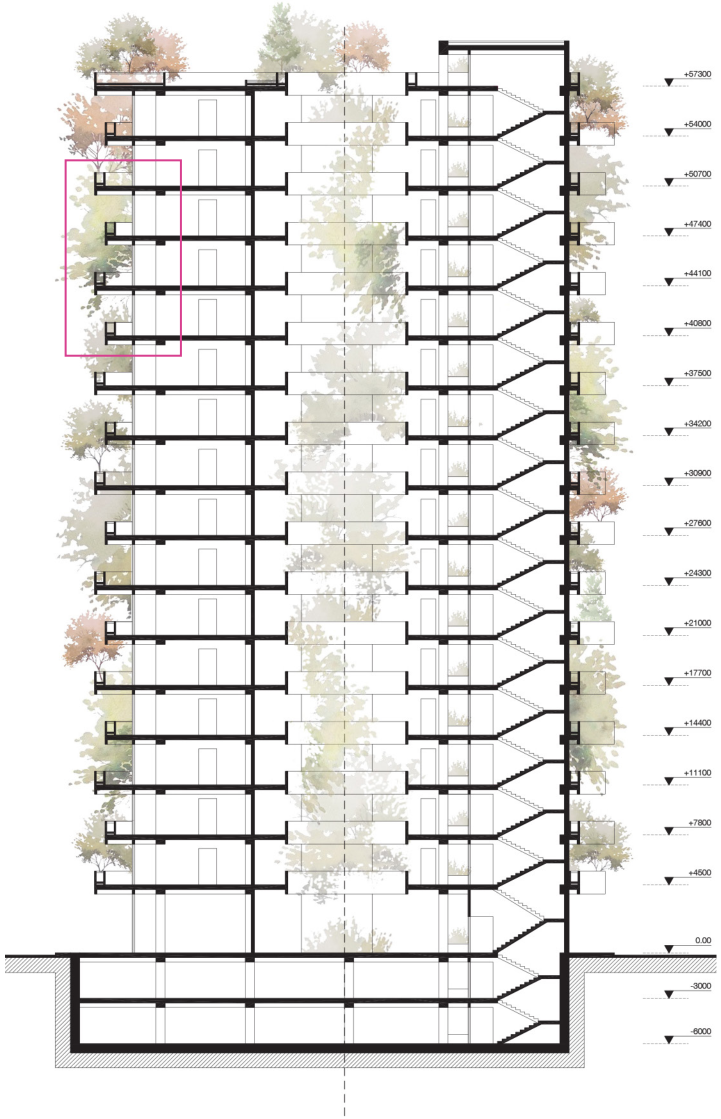


PLANT	TYPE	GROWTH/Year	DIMENSIONS	WATER DEMAND	TARGET	HABITAT	COMMENTS	COLOR: Spring I SummerI AutumnI Winter
10. Lythrum salicaria	Shrub	100 cm	H=2 m	Drought tolerant Suitable for any soil	Bees, butterflies, birds, insects	Australia, Asia Europe,America	Suitable for wetlands Not toxic	
11. Cannabis sativa	Plant	300 cm	H=3 m	Drought tolerant Prefers moist soil	Phytoremediation bees, butterflies	Cosmopolitan distribution	Moderate frost resistant, Not toxic	
12. Aster	Plant	60-90 cm	H=2 m	Drought tolerant	Phytoremediation Support 112 species	Europe, Asia	Heat resistant Not toxic	
13. Eupatorium/Joe Pye	Plant	100-150 cm	H=2 m	Drought tolerant Suitable for any soil	Butterflies, Support 42 species	America, Asia, Europe	Heat/Frost resistant, Evergreen, Not toxic	
14. Lupinus	Plant	200 cm	H=0.5-2 m	Drought tolerant Suitable for dry soil	Butterflies, birds Support 33 species	Mediterranean region,America	Toxic components	
15. Solidago/Goldenrod	Plant	120-150 cm	H=1.2-1.5 m	Well drained soil also drought tolerant	Beetles, flies, bees, wasps	America, Asia, Europe	Heat/Frost resistant, Slightly toxic	
16. Lemna minor	Floating Plant	3 to 9.5 tons/ac-year	1.5-3.5 mm	Lives on the water surface	Phytoremediation Fish,bees,insects	Europe,Africa, Asia, America	Toxicity assessment tool, Not toxic	
17. Agrostis capillaris	Grass	40 cm	H=0.4 m	Undemanding drought tolerant	Phytoremediation	Eurasia	Heat/Frost resistant, Not toxic	
18. Helianthus annuus	Crop	300 cm	H=3 m	Moderate drought tolerant	Phytoremediation Support 73 species	Cosmopolitan distribution	Slightly toxic	

Residential Building Section

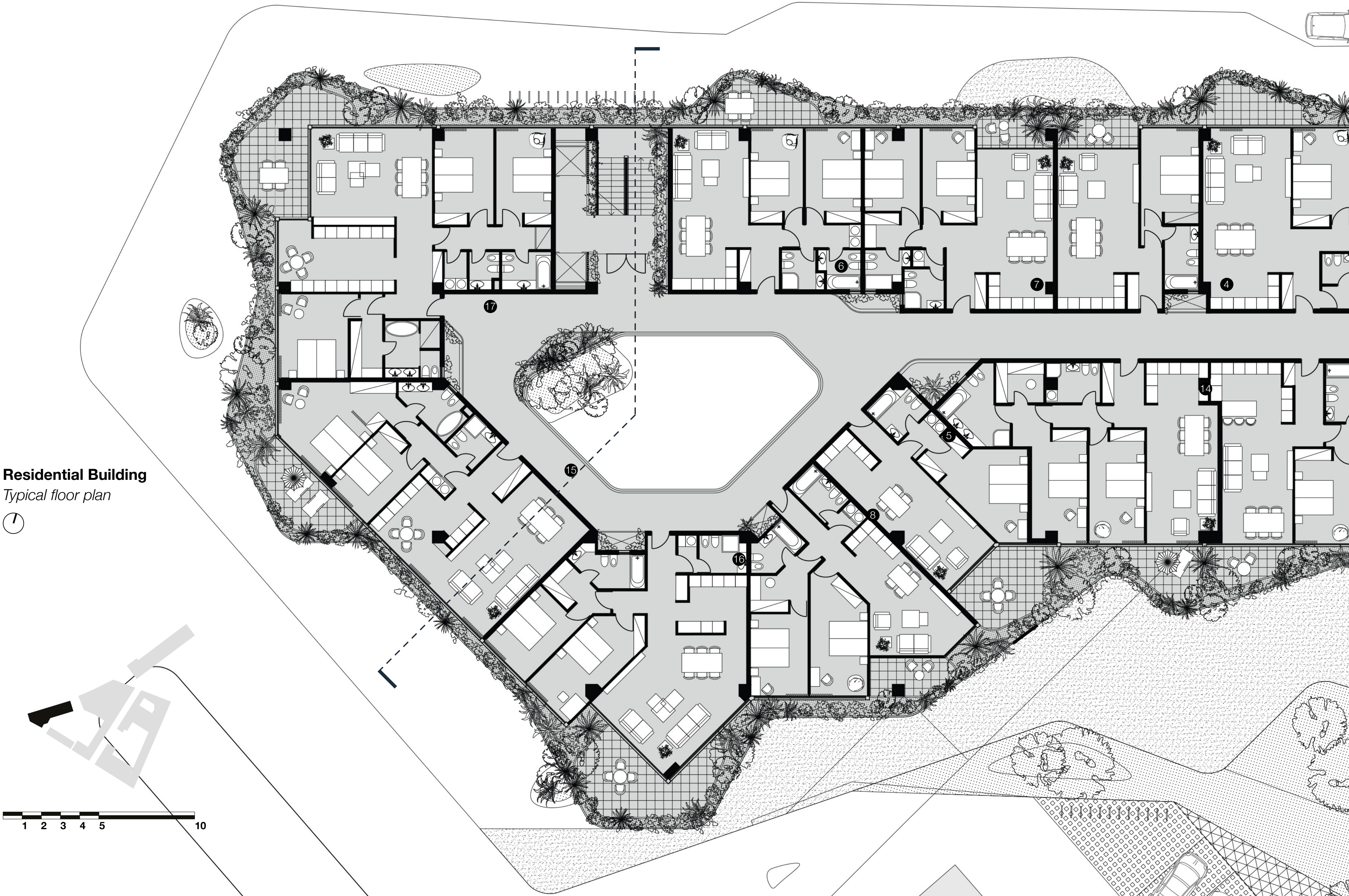
NBS benefits





Residential Building

Typical floor plan



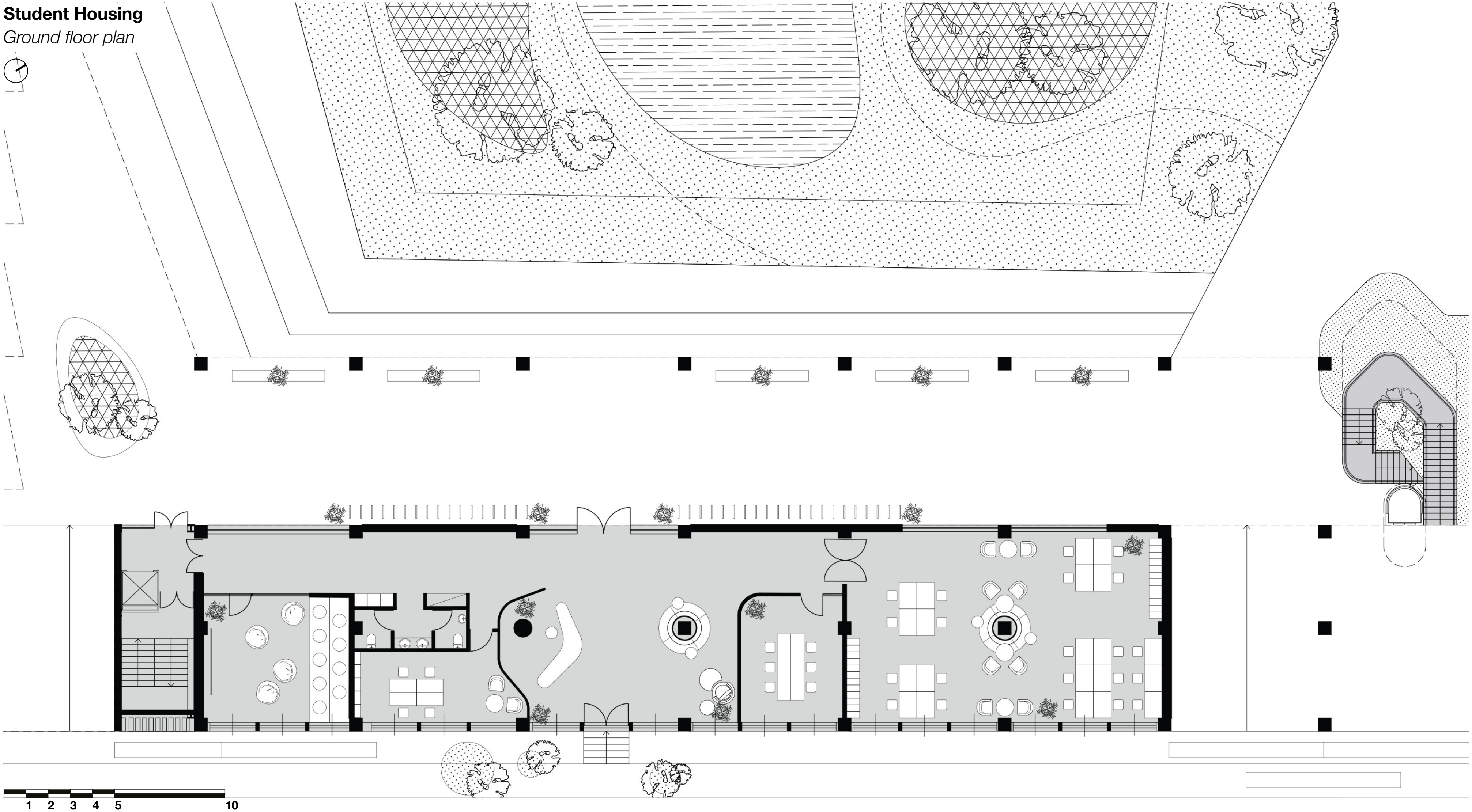
Area: 26250 m^2
Type: New Construction
Number of floors: 17 (of which 2 underground)
Construction cost: 35,700,000 €
Facilities Private green balconies, underground parking (5720 m^2 /250 cars), bike parking, ground level commercial area (3340 m^2), gym, indoor and outdoor common spaces, playground, accessible green roofs

Residential Typologies:

1. 1 Bedroom apartment - 52 m^2
2. 1 Bedroom apartment - 56 m^2
3. 1 Bedroom apartment - 60 m^2
4. 1 Bedroom apartment - 63 m^2
5. 1 Bedroom apartment - 64 m^2
6. 2 Bedroom apartment - 82 m^2
7. 2 Bedroom apartment - 85 m^2
8. 2 Bedroom apartment - 86 m^2
9. 2 Bedroom apartment - 91 m^2
10. 2 Bedroom apartment - 92 m^2
11. 2 Bedroom apartment - 92 m^2
12. 3 Bedroom apartment - 99 m^2
13. 2 Bedroom apartment - 100 m^2
14. 2 Bedroom apartment - 105 m^2
15. 2 Bedroom apartment - 114 m^2
16. 2 Bedroom apartment - 115 m^2
17. 3 Bedroom apartment - 150 m^2

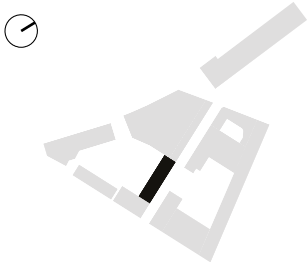
Student Housing

Ground floor plan

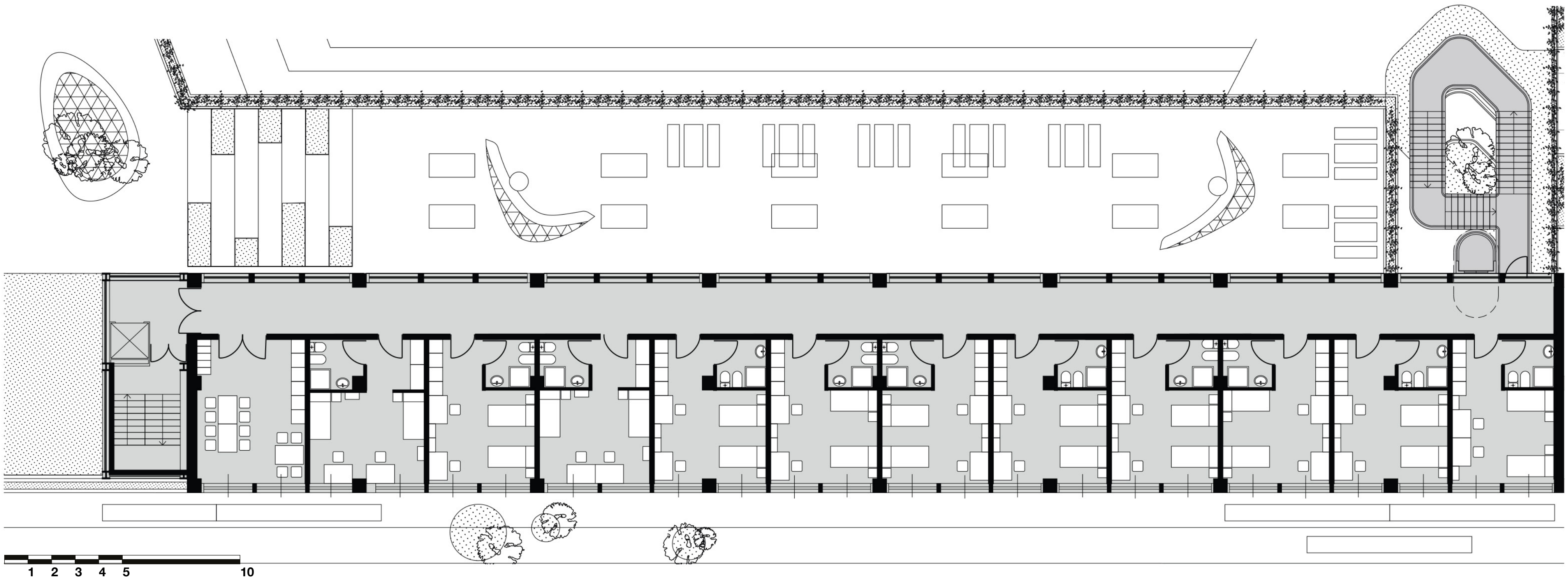


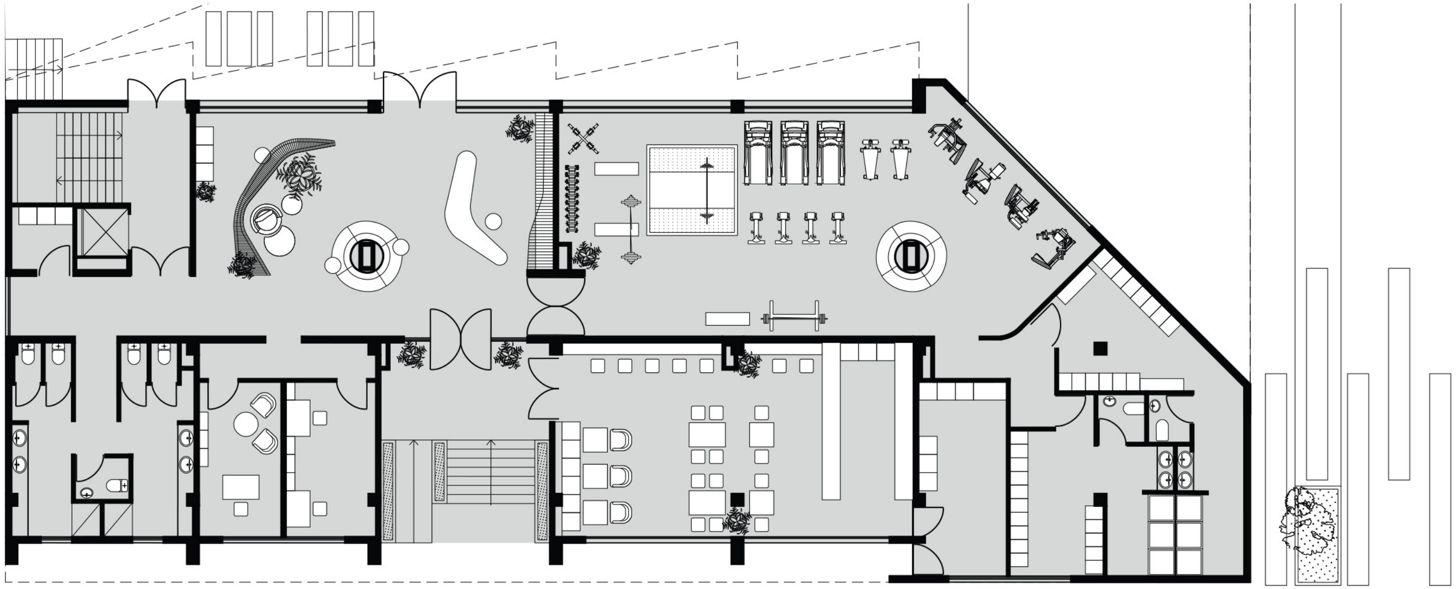
Student Housing

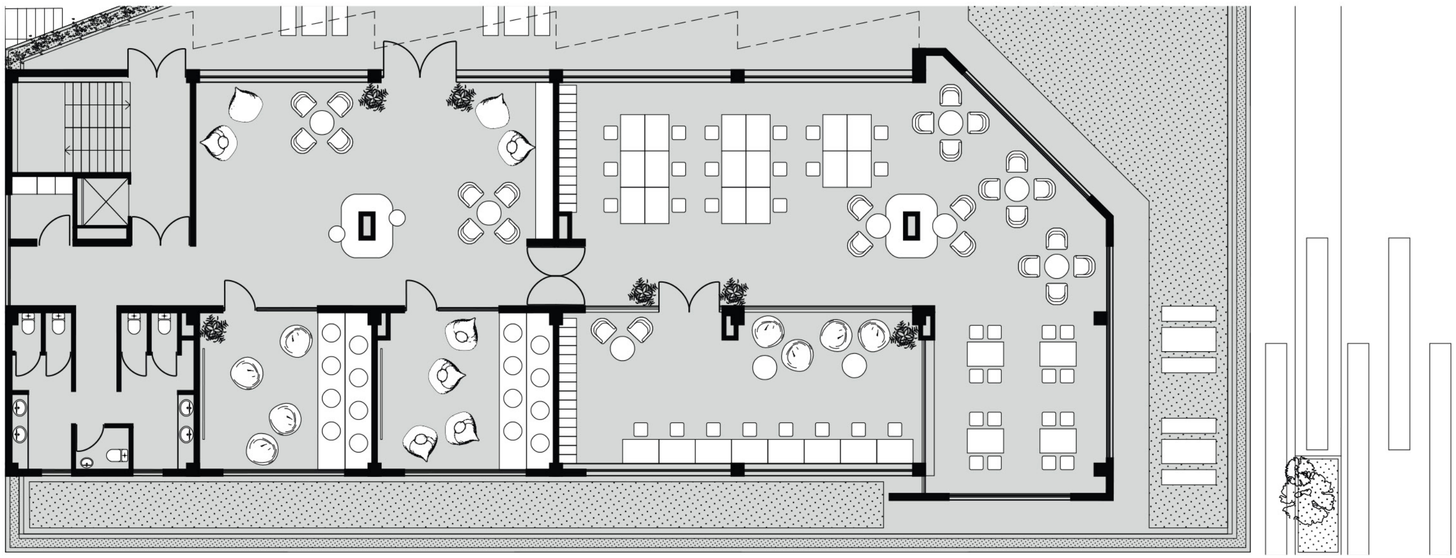
Typical floor plan



Area:	2687 m^2
Type:	Adpative Reuse
Number of floors:	4 (of which 1 underground)
Construction cost:	2,376,114 €
Rooms	22 double rooms
Facilities	Shared kitchens, indoor and outdoor common spaces, study rooms, bike parking, accessible green roof

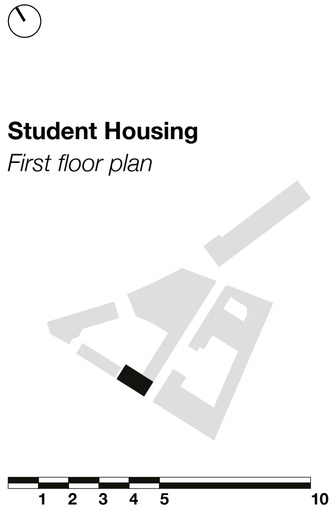






Student Housing
Ground floor plan

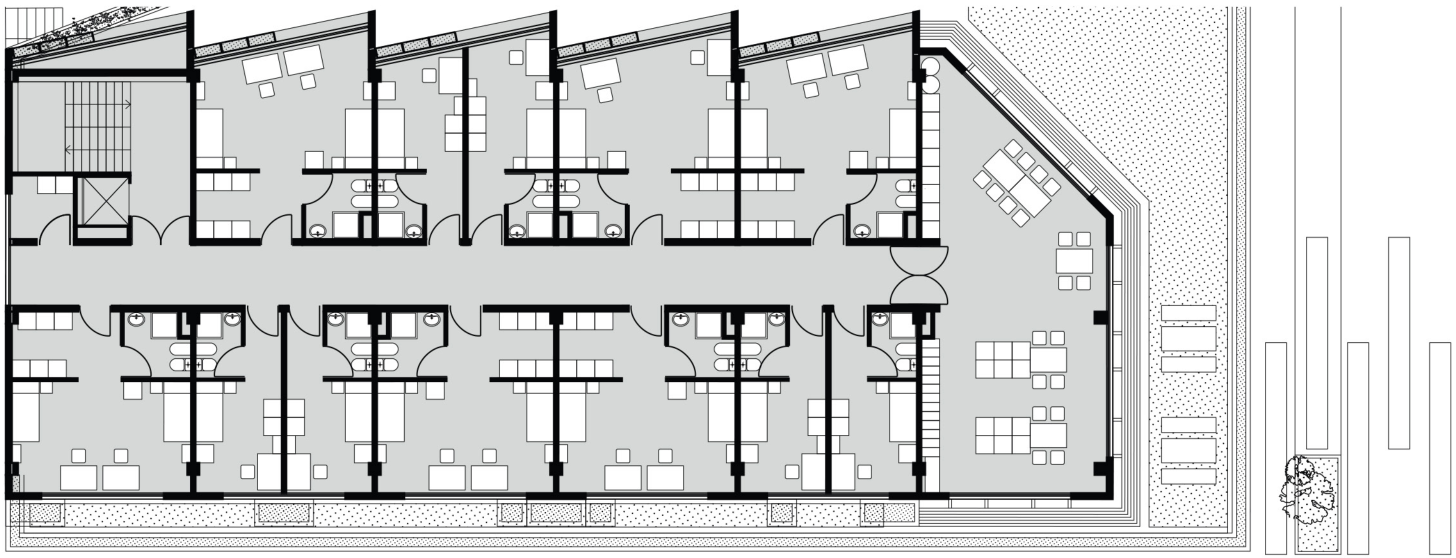
Student Housing
First floor plan



Area:	6341 m^2
Type:	New Construction
Number of floors:	11(of which 1 underground)
Construction cost:	5,406,971 €
Rooms	48 single rooms, 48 double rooms
Facilities	Shared kitchens, indoor and outdoor common spaces, study rooms, gym, café, bike parking, accessible green roof

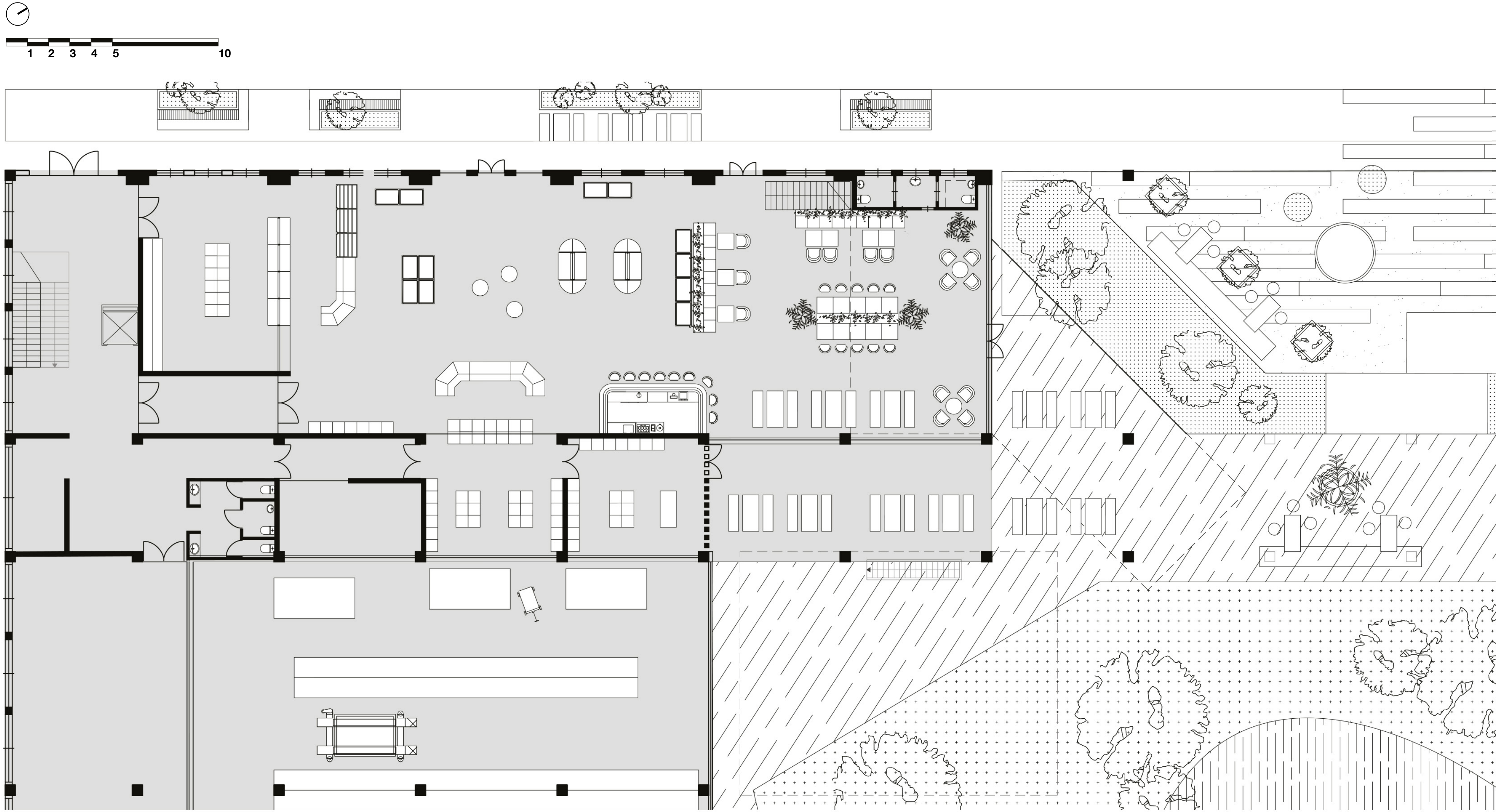
Student Housing

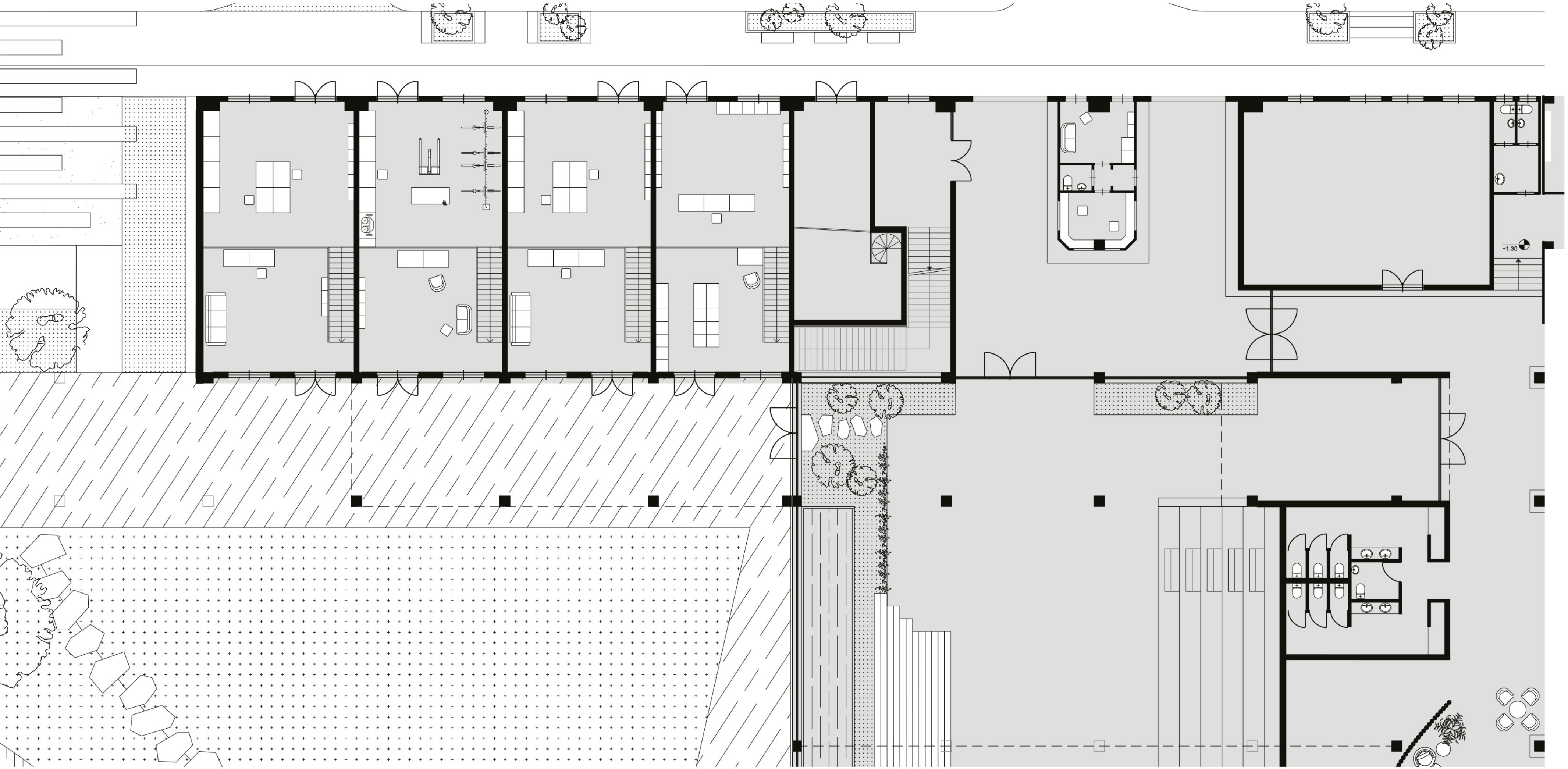
Typical floor plan



Adaptive reuse of OSI East area

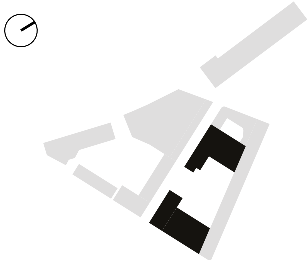
Ground floor plan



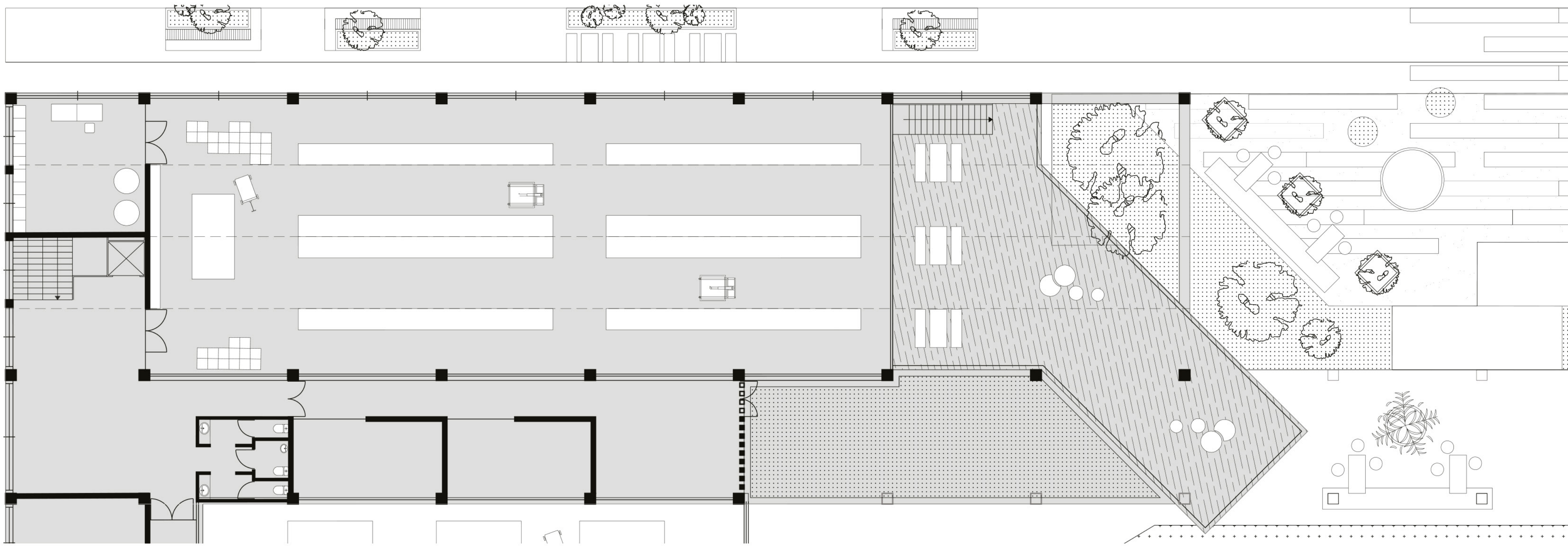

+1.30

Adaptive reuse of OSI East area

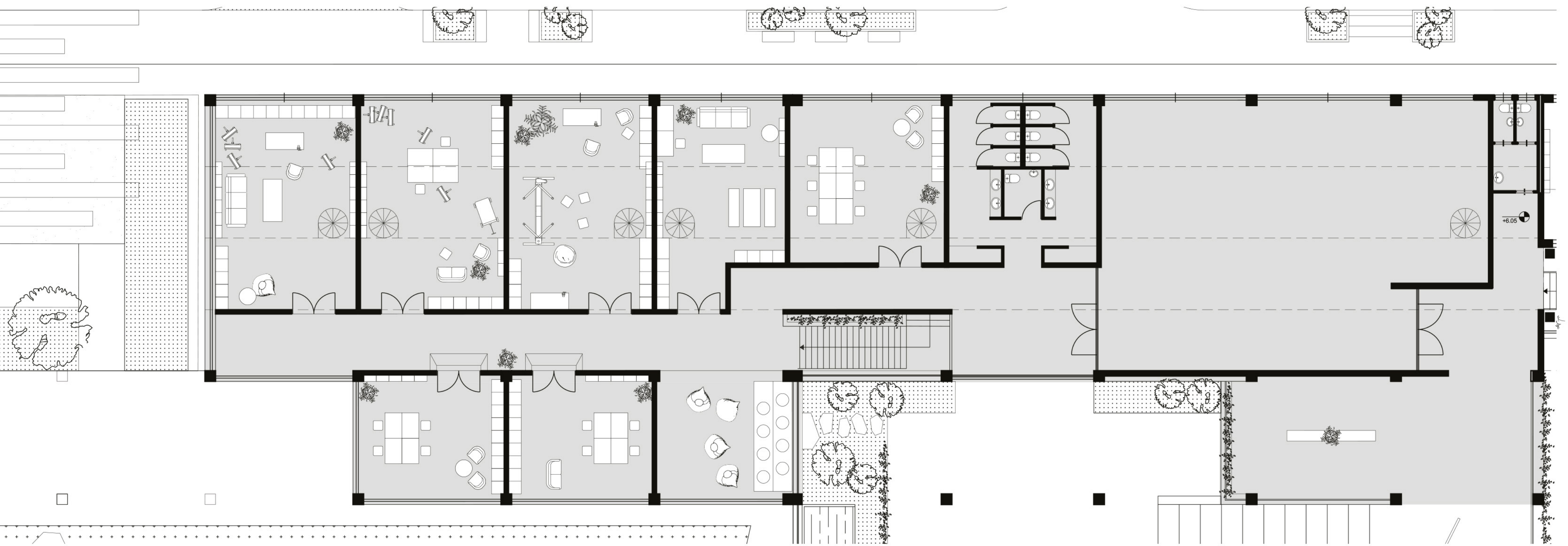
First floor plan



Area:	942 m^2
Type:	Adaptive Reuse
Number of floors:	2 (of which 1 rooftop greenhouse)
Construction cost:	987,461 €
Facilities	Food production, food preparation, food consumption, market, indoor and outdoor public spaces, accessible rooftop panoramic deck, bike parking, outdoor parking lot (30 cars)



Area: 2605 m²
Type: Adaptive Reuse
Number of floors: 2
Construction cost: 2,303,602 €
Facilities Culture and trade hub, workshop/studios, offices, multipurpose open spaces, amphitheater (500 spectators), indoor and outdoor common spaces, café, bike parking, accessible green roof



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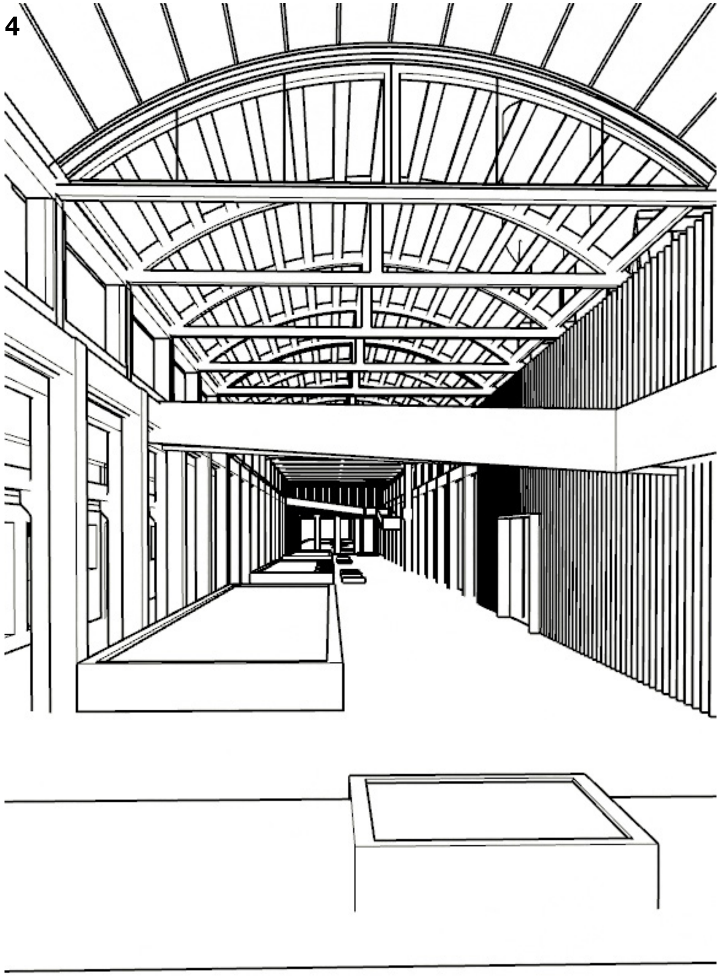

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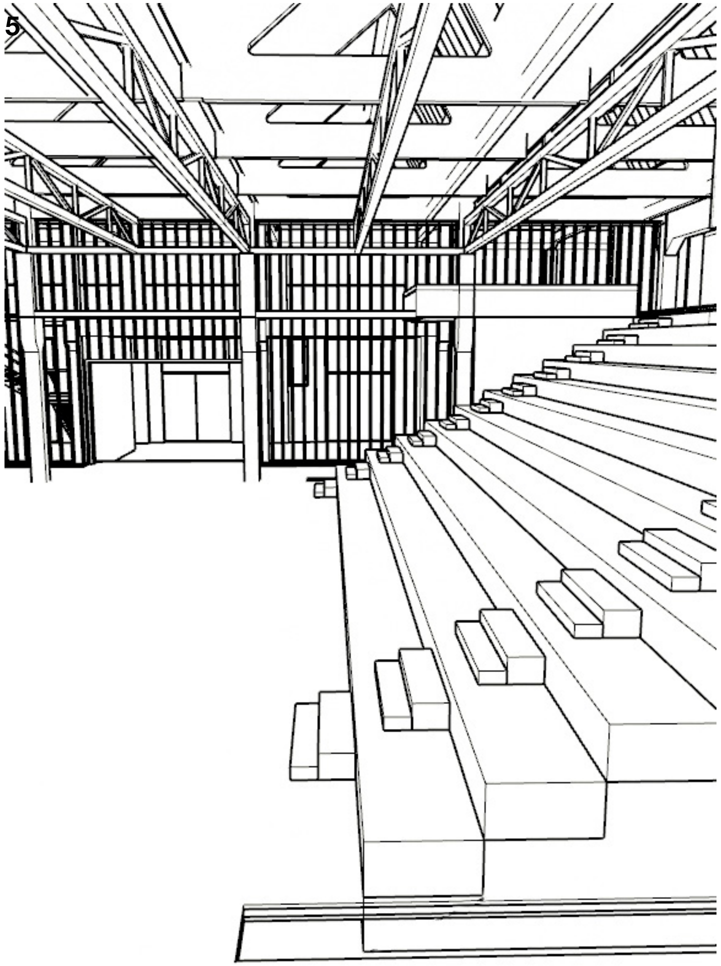
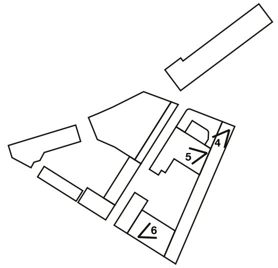
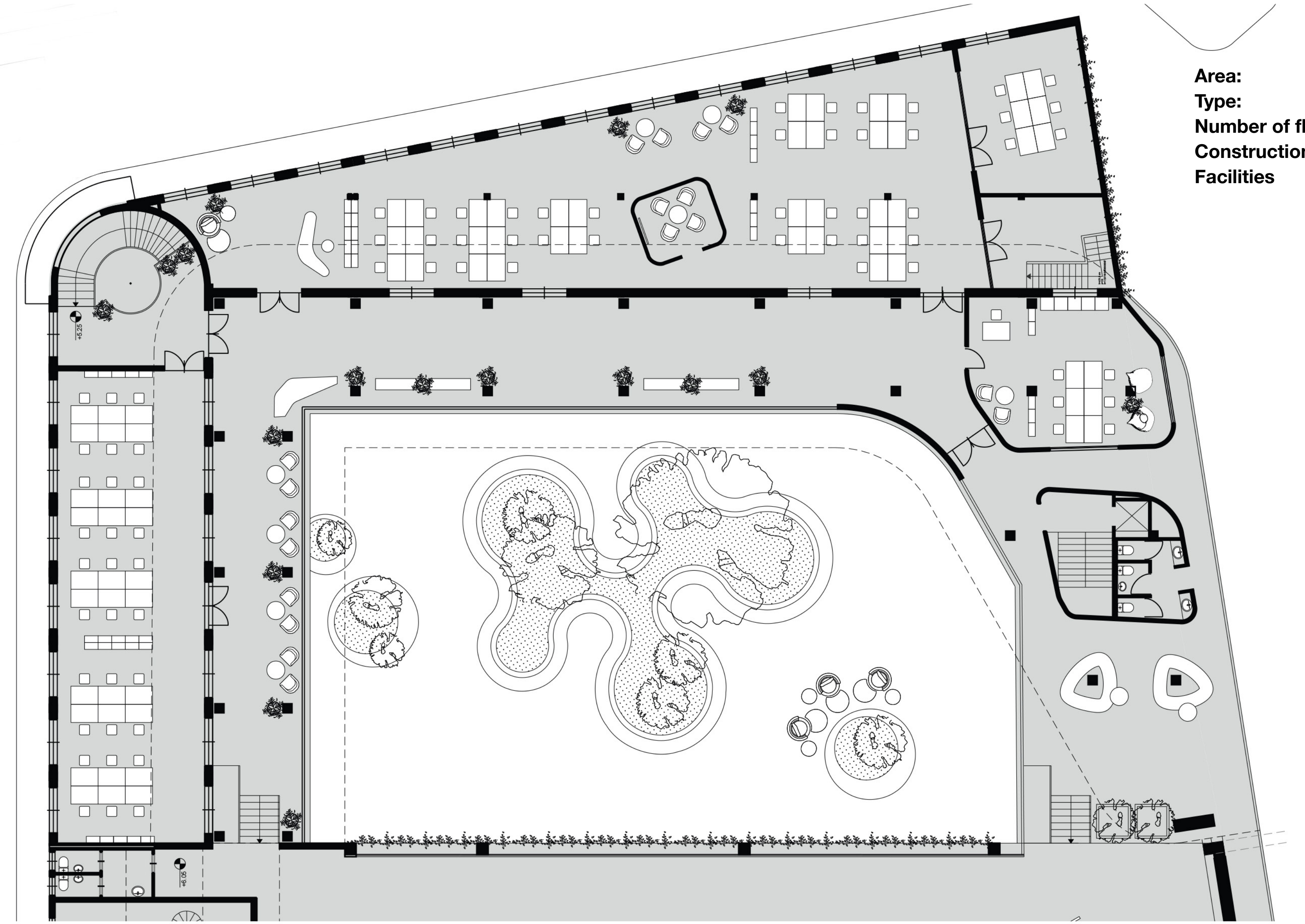


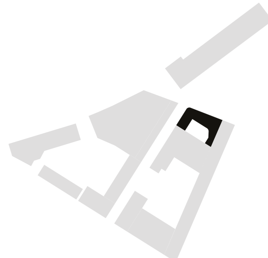


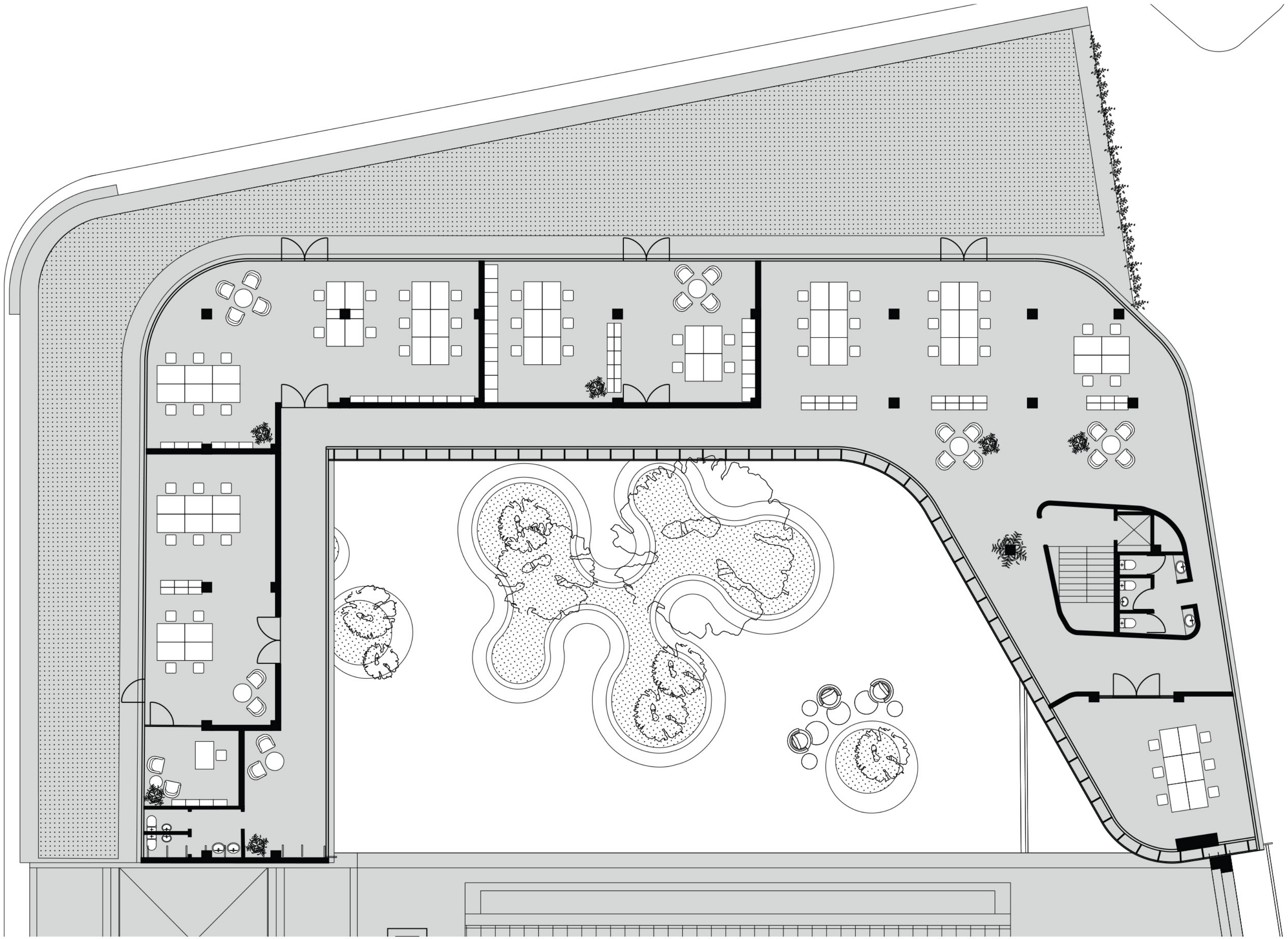


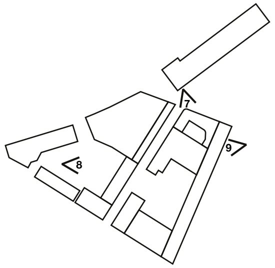
Area: 6091 m²
Type: Adaptive Reuse and Extension
Number of floors: 10 (of which 1 underground)
Construction cost: 6,702,765 €
Facilities Commercial area, indoor and outdoor common spaces, café, bike parking, underground parking, accessible green roof

Business Park
First floor plan

Business Park
2nd floor plan







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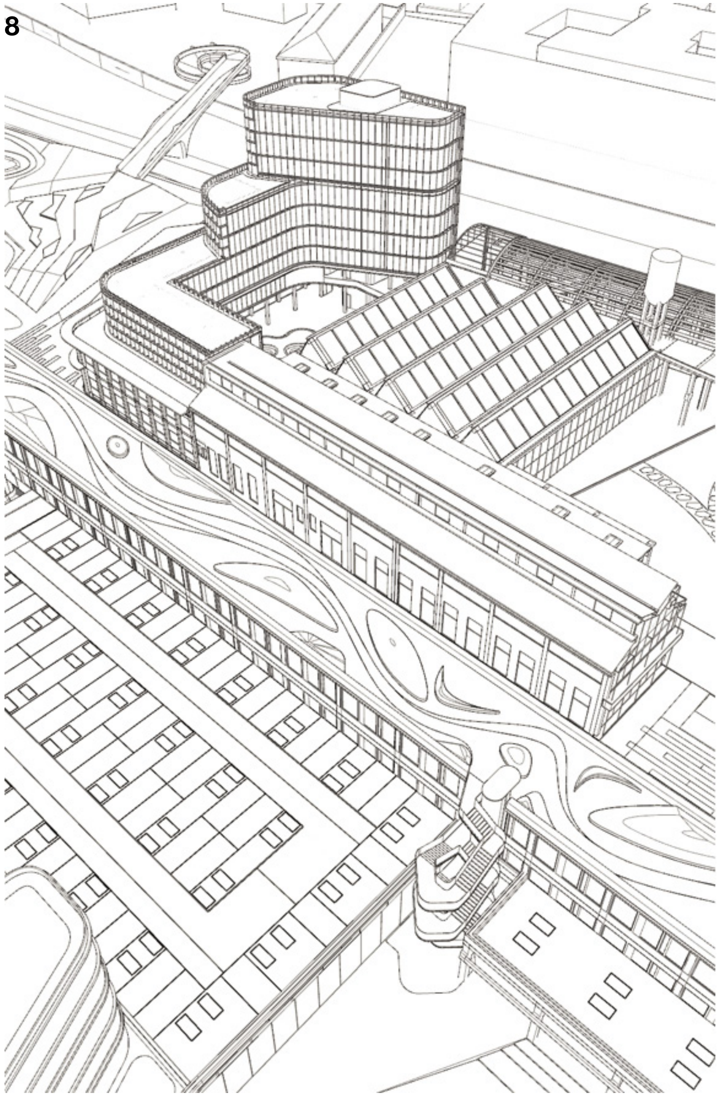

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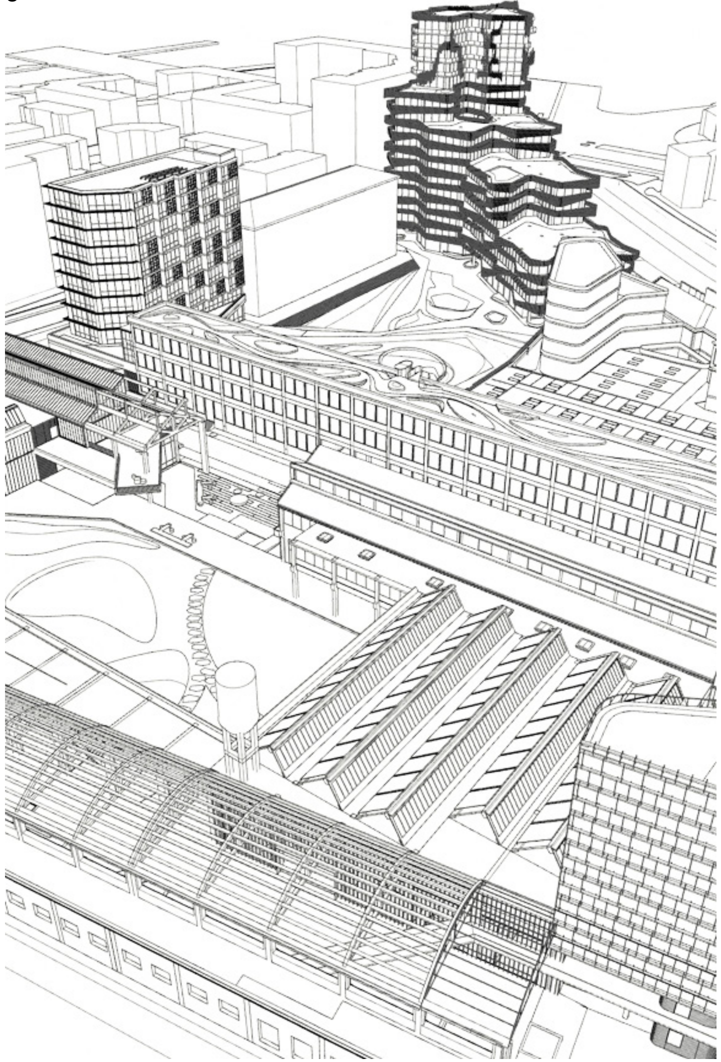
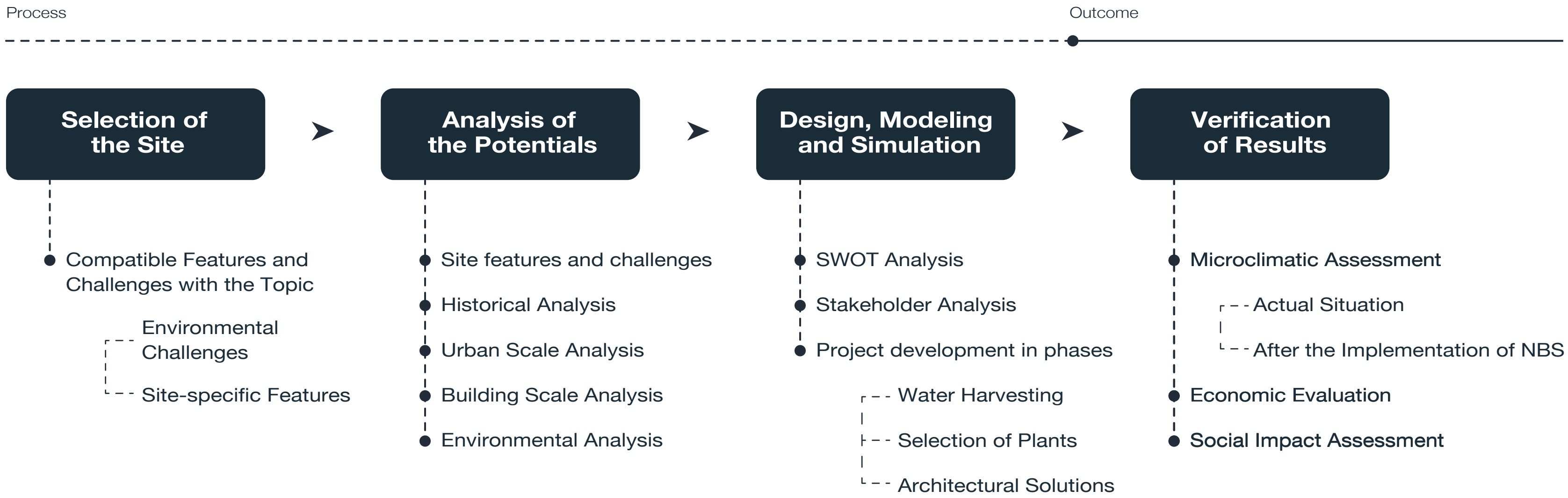



Process
Outcome
Selection of the Site
Analysis of the Potentials
Design, Modeling and Simulation
Verification of Results
Compatible Features and Challenges with the Topic
Environmental Challenges
Site-specific Features
Site features and challenges
Historical Analysis
Urban Scale Analysis
Building Scale Analysis
Environmental Analysis
SWOT Analysis
Stakeholder Analysis
Project development in phases
Water Harvesting
Selection of Plants
Architectural Solutions
Microclimatic Assessment
Actual Situation
After the Implementation of NBS
Economic Evaluation
Social Impact Assessment

Conclusion

To conclude, the feasibility of the integration and application of nature-based solutions as a tool of biophilic approach for urban adaptivity and coping with societal challenges are discussed in this research. Therefore refering to the intially raised scoping questions:

1 The study of the scientific background is a pivotal step for any experiment. Revealing the origins of NBS and the grounds for their advent as an approach was of crucial prominence to uncovering the potential of nature-based solutions as key mitigation and adaptation strategies.

2 Mitigation strategies such as reduction of energy consumption and Carbon sequestration along with adaption strategies including Urban Hydrology, Cooling the city, improving the air quality and food production and also other strategies such as enhancement of biodiversity, social and economic aspects are categorized in the framework of the research, as direct functions of NBS for the urban adaptivity. Furthermore, the potential of NBS to be integrated with other development policies and plans is discussed as its indirect action on the built environment. Ultimately, this direct and indirect actions are able to lead to the urban resilience.

3 Regarding the selection of tools, the research determined three main types:

- Nature-based strategies
- Design strategies
- Digital tools and software

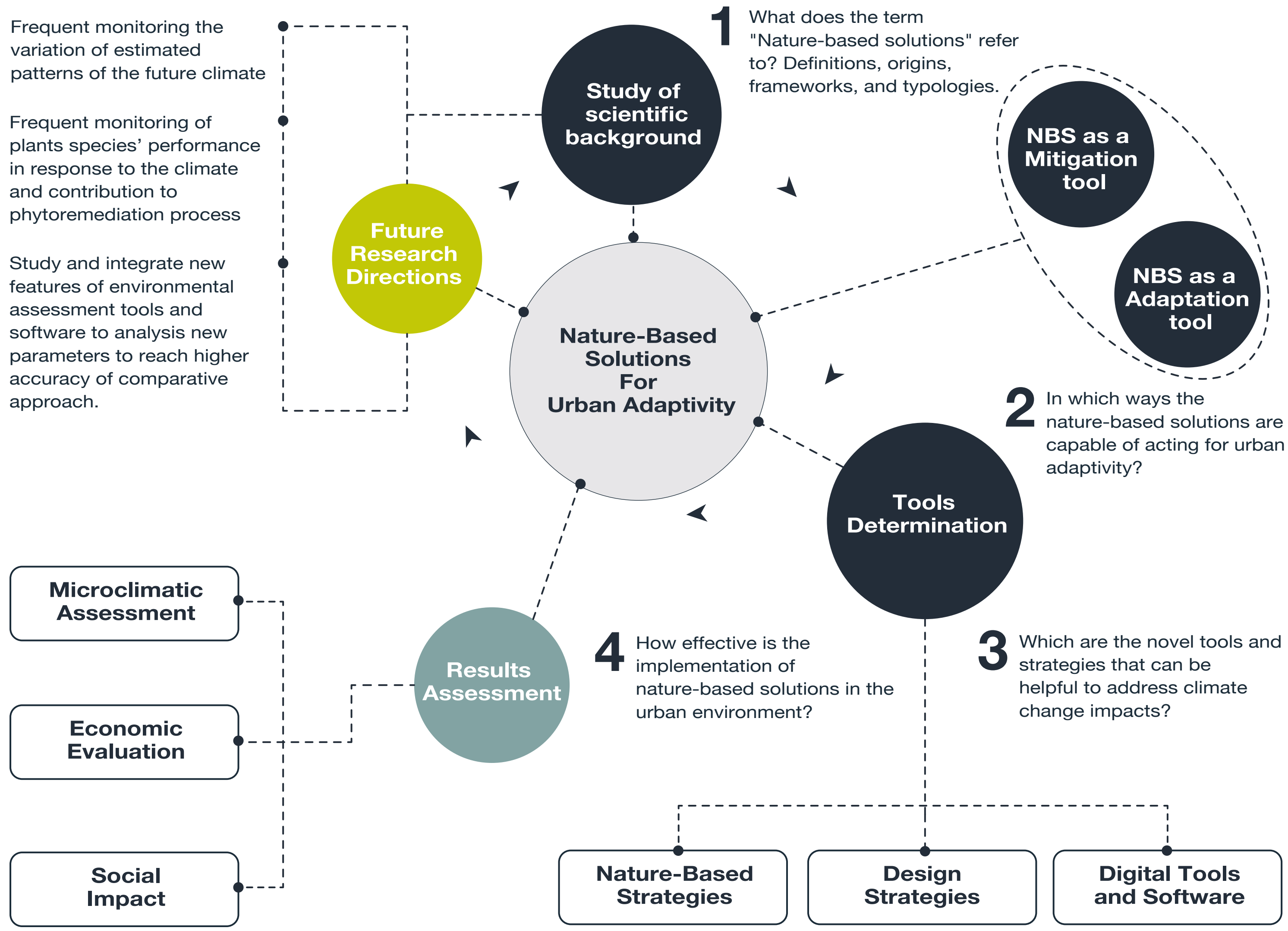
Following the profound study of NBS scientific theory and investigation of their different implementation scales, in order to define their tangible application, the research interpreted certain categories namely: building solutions, green corridors, open green spaces, bioretention areas, constructed wetlands and urban forests selected according to its site-specific characteristics. This approach has led the research process to the consideration of distinct strategies such as the integration of various types of green roofs and green facades, street tree canopies, permeable pavements, natural playgrounds, retention ponds, surface-constructed wetlands and phytoremediation chosen among the discussed categories to be studied on the model during the further stages. This comes to demonstrate that nature-based solutions are not only compatible but also an inseparable component of design strategies, being adaptive reuse, urban planning or other design approaches. Furthermore, the investigation of different digital tools dedicated to environmental analysis shed light on their potential contributions as well as their evident limitations. Envi-met software due to its ability to provide a comprehensive and holistic microclimatic assessment was chosen to be integrated into the further phases.

4 Through drawing a comparison within the micro-climatic conditions of the research site before and after the application of strategies, it is demonstrated how the hypotheses which are driven by a profound observation of influential factors on the microclimatic conditions such as the urban forms and their orientation, features of urban surfaces and vegetation can be verified as definitive strategies or undergo modifications to reach the best performance. Moreover, the simplified economic evaluation with respect to the observation of the expected cost and revenues of all three project phases driven by the sequence of the implementations and stakeholders analysis demonstrates positive estimated results. Consequently, it comes to verifying the economic feasibility of the interventions.

Overall, the research illustrates that implementing a circular approach aiming to achieve positive environmental, economic and social results is a promising pattern to reach urban resilience.

Future research directions:

Suming up, the circular approach of the research's methodology is a significant milstone and can be integrated also for the development of the future research. This circular approach leads to feasible extension opportunities to improve the aqcuracy of the final output by a frequent monitoring the variation of estimated patterns of the future climate and the performance of the plants species in respond to the climate as well as their contribution to the phytoremediation processes. Furthermore, the study of the breakthroughs in the environmental tools and software should be given prominence in order to analyse new parameters to reach higher acquiracy of comparative approach.


Frequent monitoring the variation of estimated patterns of the future climate
Frequent monitoring of plants species' performance in response to the climate and contribution to phytoremediation process
Study and integrate new features of environmental assessment tools and software to analysis new parameters to reach higher accuracy of comparative approach.
Future Research Directions
Study of scientific background
1
What does the term "Nature-based solutions" refer to? Definitions, origins, frameworks, and typologies.
NBS as a Mitigation tool
NBS as a Adaptation tool
Nature-Based Solutions For Urban Adaptivity
2
In which ways the nature-based solutions are capable of acting for urban adaptivity?
Tools Determination
3
Which are the novel tools and strategies that can be helpful to address climate change impacts?
Results Assessment
4
How effective is the implementation of nature-based solutions in the urban environment?
Microclimatic Assessment
Economic Evaluation
Social Impact
Nature-Based Strategies
Design Strategies
Digital Tools and Software

Annex

Table1

Water harvesting after interventions

Water Harvesting After Interventions						
Site	Area m2	yield coefficient /e	hN = monthly precipitation [l/m2 month]	η= hydraulic filter efficiency	Wry = monthly rainwater yield [l/month] December (minimum)	Wry = monthly rainwater yield [l/month] May (maximum)
	Flat roof,Asphalt,concrete	0.80	dec	0.80		
	Flat roof, with gravel	0.60	45.10			
	Green roof extensive,Paved surface, Bare Earth	0.50	may			
	Green roof intensive	0.30	145.30			
	Metal	0.95				
OSI West						
existing building metal roof	1,088.00				37,292.29	120,145.66
New residential intensive GR	580.00				6,277.92	20,225.76
New residential extensive GR	1,912.00				34,492.48	111,125.44
Student housing ext. GR	321.00				5,790.84	18,656.52
Student housing paved roof	229.00				4,131.16	13,309.48
student housing terrace	646.00				11,653.84	37,545.52
student housing terrace ext. GR	110.00				1,984.40	6,393.20
Non permeable roof	432.00				7,793.28	25,107.84
extensive	638.00				11,509.52	37,080.56
intensive	315.00				3,409.56	10,984.68
toolbox extensive GR	3,016.00				54,408.64	175,289.92
toolbox roof not permiable	1,170.00				33,770.88	108,800.64
toolbox extensive GR extension	362.00				6,530.48	21,039.44
OSI West garden	3,368.00				36,455.23	117,448.90
OSI EAST						
non permiable roof	7,935.00				229,035.84	737,891.52
extensive GR	1,052.00				18,978.08	61,142.24
water harvesting	653.00				7,068.07	22,771.42
OSI EAST garden	2,868.00				31,043.23	100,012.90
GHIA						
concrete roof	3,850.00				111,126.40	358,019.20
wetland	2,608.00				28,228.99	90,946.18
Total calculated area	33,153.00					
total site	50,725.00					
non permiable streets and sidewalks	17,572.00				507,198.21	1,634,055.42
			Total water volume		1,188,179.34	3,827,992.43

Table 2
Costs

N	PHASE I Works	Unit	Quantity	Time	Cost per unit[€]	Total [€]	Source
2	**Adaptation for temporary use (GHIA gallery)**	m2	3715				
	Electricity	m2	3715	1 week	$ 70.00	$ 260,050.00	DEI2019, D21,p.193
	Sanitations system	m2	30	1 month	$ 128.17	$ 3,845.10	DEI2019, D21,p.193
	Temporary floor ramp	m2	80		$ 52.00	$ 4,160.00	https://rainieroutdoor.com/blog/yurt-living/true-cost-yurt-
2.1	**Adaptation for temporary use (GHIA building)**	m2	936	4 moths	$ 620.00	$ 580,320.00	DEI2019, D21,p.193
3	**Dismantling of the OSI West area**	m2 (gfa)	8199	3 weeks	$ 15.00	$ 122,985.00	DEI2019, I214,p.422 https://www.researchgate.net/publication/290430695_DECONSTRUCTION_CASE_STUDY_IN_SOUTHERN_ITALY_ECONOMIC_AND_ENVIRONMENTAL_ASSESSMENT
3.1	Demolition with excavators equipped with hydraulic pincers on a 50 meters long arm, including the primary crashing and iron separation. (empty spaces included)						
3.2	Transportation with tracks to CDW treatment installation						
4	**Toolbox façade renovation:**			3 months			
4.1	Green wall	m2	146	1-2 months	$ 120.00	$ 17,520.00	Price Analysis
4.2	External glass wall with openings	m2	492	2 weeks	$ 215.00	$ 105,780.00	https://www.shoesoffclub.com/blog/parete-divisoria-in-vetro-prezzi-ed-info#:~:text=Il%20costo%20al
4.3	Façade wooden cladding	m2	159	1-2 months	$ 150.00	$ 23,850.00	https://www.mortlock.com.au/learning/how-much-does-timber-cladding-cost/#:~:text=For%20an%2018mm%20thick%20board,scope
4.3	Rooftop plant boxes and greening	m2	53	3-5 months	$ 150.00	$ 7,950.00	Price Analysis
5	**Construction of New residential building**	m2	26250	25 months	$ 1,360.00	$ 35,700,000.00	DEI2019, A9,p.45
6	**Possible Construction of new office building (Toolbox)**	m2	1750	13 months	$ 1,280.00	$ 2,240,000.00	DEI2019, D20,p.189
7	**Construction of Public square**	m2	4587	4 months	$ 42.00	$ 192,654.00	DEI2019, I8,p.405 / DEI2019, I14,p.422
8	**Adaptive reuse Student housing:**						

8.1	**The Building:**	m2	2687	12 months	$ 884.30	$ 2,376,114.10	DEI2019, D21,p.193
8.2	**Semi intensive green roof**	m2	540	1 month	$ 150.00	$ 81,000.00	Price Analysis
8.3	**Stairs to roof**	m	47	6 weeks	$ 350.00	$ 16,450.00	https://tirichiamo.it/page/Ristrutturazioni/Scale/Scale-in-Ferro-Prezzi-Permessi-
9	**Toolbox rooftop parking conversion into permeable surface**	m2	1963	3 months	$ 53.00	$ 104,039.00	Price Analysis
10	**Construction of semi intensive green roof [Toolbox eastern block]**	m2	737	1 month	$ 150.00	$ 110,550.00	Price Analysis
11	**Construction of NEW student housing:**	m2	6341	18 months	$ 852.70	$ 5,406,970.70	DEI2019, A9,p.45/ DEI2019, A12,p.58/ Costi per tipologie edilizie p.186
12	**Construction of extensive green roof (Toolbox WEST)**	m2	1195	3-5 months	$ 120.00	$ 143,400.00	Price Analysis
12.1	Photovoltaic plant	m2	100	1 week	$ 1,100.00	$ 110,000.00	https://www.allenergya.com/news/costo-impianto-fotovoltaico-20-kw/
					Construction Cost (CC)	**44,867,849**	

	PHASE II						
13	**Dismantling of the OSI East (mentioned structures):**	m2	6178	3 weeks	15	92,670	https://www.researchgate.net/publication/290430695_DECONSTRUCTION_CASE_STUDY_IN_SOUTHERN_ITALY_ECONOMIC_AND_ENVIRONMENTAL_ASSESSMENT
14	**Installation of water harvesting systems**	m2	2500	2 months	8	20,000	DEI2019, I8,p.405 /
15	**Phytoremediation (plants)**						Price Analysis
15.1	plants	cad				9,750	Price Analysis
15.2	transportation	m3	6			2,500	https://www.traslochi24.it/servizi-traslochi/trasporto-piante/
16	**Converting an existing street into a pedestrian street**	m2	1870	2 months	25	46,750	DEI2019, I8,p.405 / DEI2019, I14,p.422
17	**Adaptive reuse of food blocks (restaurant/ green house)**	m2	942	6 months	884.3	833,011	DEI2019, D21,p.193
	Rooftop – green house 570 mq	m2	780	6 months	510	397,800	Price Analysis
18	**Adaptive reuse of cultural block**	m2	2605	6 months	884.3	2,303,602	DEI2019, D21,p.193
	PV plant 244 mq panels surface (122x2)	m2	120	1-2 weeks	1100	132,000	https://www.allenergya.com/news/costo-impianto-fotovoltaico-20-kw/

19	**Adaptive reuse of gallery highline green passage**	m2	657	4 months	42	27,594	
	Semi intensive GR -657 mq						Price Analysis
19.1	Wine bar 180 mq		180		884.3	159,174	
19.2	Ramp to internal yard	m	150	2 months	700	105,000	https://www.archiexpo.it/prod/fehr/product-125015-1237293.html
20	**Construction: Extension of office building (OSI EAST)**	m2	3327	14 months	1280	4,258,560	DEI2019, D20,p.189
20.2	Green roofs	m2	615	1 month	120	73,800	Price Analysis
21	**Adaptive reuse of existing office building (OSI EAST)**	m2	2764		884.3	2,444,205	DEI2019, D21,p.193
22	**Construction: Expansion of green house**						
22.1	Adaptive reuse to green house 1296 mq	m2	1296	4 months	510	660,960	Price Analysis
22.2	extensive Green roof 374 mq	m2	374	1 month	150	56,100	Price Analysis
22.3	Pv plant 792mq panels surface (4x198)	m2	792	1-2 weeks	80	63,360	https://www.allenergya.com/news/costo-impianto-fotovoltaico-20-kw/
23	**Dismantling: Re-opening the underpass crossing the bridge**	m2	200	1 month	25	5,000	https://www.researchgate.net/publication/290430695_DECONSTRUCTION_CASE_STUDY_IN_SOUTHERN_ITALY_ECONOMIC_AND_ENVIRONMENTAL_ASSESSMENT
24	**Construction of new pedestrian bridge (East)**	m	59	4 months	8047	474,773	DEI2019, D23,p.212
25	**Dismantling of office buildings in GHIA area**	m2	1885	3 weeks	15	28,275	https://www.researchgate.net/publication/290430695_DECONSTRUCTION_CASE_STUDY_IN_SOUTHERN_ITALY_ECONOMIC_AND_ENVIRONMENTAL_ASSESSMENT
26	**Construction of Public square**	m2	2500	4 months	42	105,000	Prezzi tipologie edilizie p.342
					Construction Cost (CC)	**12,299,883**	
	PHASE III						
27	**Construction of urban wetland**	m2	2700	4 months	18	48,600	Price Analysis
28	**Adaptive reuse of the GHIA building**	m2	3715	8 months	884.3	3,285,175	DEI2019, D21,p.193
29	**Construction of new pedestrian bridge (West)**	m	49	4 months	8047	394,303	Costi per tipologie edilizie p.212
					Construction Cost (CC)	**3,728,078**	

RATE [%]	2.50%
AMOUNT [€]	81,977,695.43
TERM [years]	15

INSTALLMENT	6,621,047.94 €	
TEST 1	$ 6,621,047.94	NO
TEST 2	OK	

INTEREST (15y)	17,338,023.60 €

YEARS	INSTALLMENT	INTERESTS PAYMENT	PRICIPAL PAYMENT	PRINCIPAL PAYED	TO BE PAID
					81,977,695.43 €
1	6,621,047.94 €	2,049,442.39 €	4,571,605.55 €	4,571,605.55 €	77,406,089.89 €
2	6,621,047.94 €	1,935,152.25 €	4,685,895.69 €	9,257,501.24 €	72,720,194.20 €
3	6,621,047.94 €	1,818,004.85 €	4,803,043.08 €	14,060,544.32 €	67,917,151.12 €
4	6,621,047.94 €	1,697,928.78 €	4,923,119.16 €	18,983,663.48 €	62,994,031.96 €
5	6,621,047.94 €	1,574,850.80 €	5,046,197.14 €	24,029,860.61 €	57,947,834.82 €
6	6,621,047.94 €	1,448,695.87 €	5,172,352.07 €	29,202,212.68 €	52,775,482.76 €
7	6,621,047.94 €	1,319,387.07 €	5,301,660.87 €	34,503,873.54 €	47,473,821.89 €
8	6,621,047.94 €	1,186,845.55 €	5,434,202.39 €	39,938,075.93 €	42,039,619.50 €
9	6,621,047.94 €	1,050,990.49 €	5,570,057.45 €	45,508,133.38 €	36,469,562.05 €
10	6,621,047.94 €	911,739.05 €	5,709,308.88 €	51,217,442.27 €	30,760,253.17 €
11	6,621,047.94 €	769,006.33 €	5,852,041.61 €	57,069,483.87 €	24,908,211.56 €
12	6,621,047.94 €	622,705.29 €	5,998,342.65 €	63,067,826.52 €	18,909,868.92 €
13	6,621,047.94 €	472,746.72 €	6,148,301.21 €	69,216,127.73 €	12,761,567.70 €
14	6,621,047.94 €	319,039.19 €	6,302,008.74 €	75,518,136.47 €	6,459,558.96 €
15	6,621,047.94 €	161,488.97 €	6,459,558.96 €	81,977,695.43 €	0.00 €
		17,338,023.60 €	81,977,695.43 €		

Table 3
Loan Conditions

REVENUES						
N		Type	Unit	Quantity	Price per unit[€]	Total revenue[€]
1	GHIA area existing structure	Temporary use Rental	m2	3715	11	490,380
2	New residential building:	Sale				
2.1	Residential	Sale	m2	17367	3000	52,101,000
2.2	Commercial	Sale	m2	1526	2250	3,433,500
2.3	Parking	Sale	m2	5720	1900	10,868,000
3	Student housing (2687m2)	Adaptive reuse for Rental	double room	24	800	230,400
3.1	non rsidential use	Rental	m2	1924	12	277,056
4	New student housing (6341m2)	Rental				
4.1			double room	48	800	460,800
4.2			single room	48	600	345,600
4.3	non rsidential use	Rental	m2	1957	12	281,808
5	Food court	Sale	m2	942	2250	2,119,500
6	rooftop green house	Sale	m2	780	1700	1,326,000
7	Cultural block	Sale	m2	3105	2100	6,520,500
8	Office Building	Sale	m2	4947	2100	10,388,700
8.1	Underground parking	Sale	m2	1644	1900	3,123,600
9	Expansion of Green house	Sale	m2	2108	1700	3,583,600
10	Adaptive reuse of the GHIA building	Sale	m2	3715	2100	7,801,500

Table 4
Revenues

Authors’ Contribution

The thesis is developed by a group of two: Arin and Lousineh. Having common interests and inspiration on the topic the authors have developed the concept and methodology of the research together.
Afterward, each of the authors developed distinct portions of the theory: The second chapter is developed by Arin and the 3rd chapter by Lousineh. Having concluded the theory the authors came up with several case studies each, and after discussions, five of them were selected to be inserted in the 5th chapter.
The analytical and experimental part in chapter 6 is also developed by both authors:
Building-scale Analysis, 3D modeling, Microclimatic assessment by Arin and Historical Analysis, Environmental Analysis, and Economic Evaluation by Lousineh. Both authors have their contributions to the Urban-scale Analysis, development of the Master plan, Architectural drawings, Graphical development, and presentation.

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