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Innovation, green infrastructures and urban form

Towards regenerative city models

In the contemporary global context—characterized by increasing environmental pressures, demographic asymmetries, and socio-economic fragmentation and structural inequalities—the relationship between urban form, ecosystem services, and territorial innovation acquires unprecedented strategic value. This Special Issue intends to critically explore and foster a new interdisciplinary debate aimed at rethinking the urban project within a framework of regenerative and systemic transformation.

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EDITORIAL PREFACE

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1 Introduction

In the contemporary global context, characterized by increasing environmental pressures, demographic asymmetries, and socio-economic fragmentation and structural inequalities, the relationship between urban form, ecosystem services, and territorial innovation acquires unprecedented strategic value. This Special Issue intends to critically explore and foster a new interdisciplinary debate aimed at rethinking the urban project within a framework of regenerative and systemic transformation.

Historically, cities have developed through a complex co-evolution of built forms and ecological systems. The integration between public spaces, green infrastructures, and urban morphology has not only structured the spatial configurations of the urban fabric but also supported green and blue infrastructures and multiple ecosystem services (Tzoulas et al., 2007; Valente et al., 2020; Salmond, 2016). In fact, the study of the relationship between the natural and artificial components of human settlements and how this relationship can give rise to interesting processes of urban morphogenesis is of relevance today. Yet, in many contexts, such integration has occurred incidentally, without being embedded in organic and strategic planning and design visions. Thus, it should not be forgotten that a part of the international urban planning community began reflecting on this topic many years ago, following research in urban and environmental ecology (Commoner, 1971). The ecosystem approach to the analysis and planning of the modern city finds its roots in the debate that emerged, particularly in Europe, between the late 1980s and early 1990s. The importance of the systemic approach in studying urban phenomena, combined with the intuition of the enormous potential of new technologies in shaping new configurations of human settlement, was explored alongside the growing awareness of the need to shape urban evolution through the development of a green system that is deeply integrated with other urban subsystems. "If optical fibers can make data, information, knowledge, and services travel through space in real time, transforming the movement of goods and people, which has traditionally defined urban areas based on vehicular logic, and if the new model of the wired city enables humans to overcome the constraints of spatial proximity, then the creation of an organic green sub-system within urban centers seems suited to overcoming the limitations of a development model rooted in a profound dichotomy with nature" (Gargiulo & Papa, 2021; Papa et al., 2021). The importance of the natural-green component within cities, which were expanding significantly in their material and spatial dimensions, was acknowledged

and emphasised in many studies and reports, including the well-known Green Paper on the Urban Environment published in July 1990 by the European Commission (1990). There was, without doubt, a growing awareness and a sufficient level of maturity in the belief that urban greenery should not be regarded as a marginal function of the city system, but rather as one of the key dimensions of urban transformation. In fact, the design and development of green space should be far from being a mechanical operation of planting arrangement or the adaptation of predefined schemes to different sites; rather it should follow a precise methodological process leading to a design hypothesis informed by multiple factors of different nature (Trupiano & Fistola, 1989). Today, it is important to revisit and update those reflections, reconsidering their systemic dimension. The eco-environmental component should be recognised as one of the most relevant urban subsystems. As a subsystem of the urban system, it must appropriately interact with the material space of the physical-spatial subsystem. In this sense, within a renewed foundational approach to territorial transformation governance, the urban natural dimension must be appropriately envisioned within a specific process. Three successive stages can be identified in this process:

- The first involves assessing and quantifying the existing green areas within each urban zone and subsequently calculating the amount of CO_2 they capture. As an initial, rapid evaluation of urban livability, this data can be compared with pollution levels in the same area;
- The second stage considers the relationship between ecosystem services and the land uses planned in the urban planning tool, to preliminarily evaluate their compatibility based on the activities to be implemented (Fistola, 2023);
- The third stage requires direct public engagement in evaluating and considering green transformations, envisioning their location and form in the urban context where they will take place. This perceptual prefiguration can be made possible by developing extended reality applications that citizens can install on their smartphones and use to "see" the proposed green spaces.

Although during the history of modern urban planning (Hall, 2014; Lemes De Oliveira, 2020) solutions of integration between urban form and the shape of urban green space (green belts, ecological corridors, green wedges) have often been experimented, the theme of an effective unitary conception of urban space has gradually disappeared from the horizon of urban studies. The design of urban green spaces (and sometimes even extra-urban ones) has become over time an increasingly sectoral topic, treated by specialists. Urban forestry, the design of urban parks, integrated arrangements between buildings and green infrastructure (such as green roofs or urban agriculture) have become topics theoretically treated by specialists and addressed separately from the design of urban space.

In the history of urban planning, however, there are experiments that have optimally combined the two themes of urban form and green space. It is enough to mention the first English and then European experiences of green belts and wedges (it is enough to mention the London plan by Abercrombie or the "five fingers" plan of Copenhagen) and the vast range of American experiences pertaining to the strand of environmental design.

Urban forms and green space are to some extent the positive and negative reading of an urban space that is actually unitary. And the form of the built environment conditions and in turn is conditioned by the form of the green space, external and internal to the city.

Today, the regenerative approach proposes a fundamental redefinition of this relationship. It calls for the embedding of ecological principles in urban planning and design, configuring green infrastructures as multi-scalar systems of ecological and social connectivity. This requires overcoming rigid and sectoral planning tools and adopting the concept of resilience that represents a new vision of sustainability, concerning a new approach based on multifunctionality, adaptation, redundancy, diversity (Ahern, 2011; Sharifi & Yamagata, 2018; Escolà-Gascón et al., 2024).

Concepts such as urban greening, green infrastructure, ecosystem-based adaptation, and more recently, nature-based solutions, are being widely adopted to emphasize the importance of urban ecosystems as

essential infrastructure for the sustainability of cities (Gutierrez-Velez, 2022). Examples such as the Superblocks of Barcelona (Rueda, 2019), or urban-rural sustainability integration (ESPON, 2014) demonstrate how urban morphology and green infrastructure can be strategically integrated to reduce socio-spatial inequalities and generate new forms of sustainability and urban resilience.

According to Rueda (2019), contemporary cities suffer from excessive car usage, which has serious consequences in terms of pollution, noise, insecurity, and unequal access to public spaces. The case of Barcelona's Superblocks is a prime example of contemporary urban regeneration. Starting in 2016, the Catalan city began a profound transformation of its public spaces with the aim of reducing the impact of vehicle traffic, improving air quality, and reclaiming space for people. The principle behind the project is simple yet effective: group nine urban blocks together to form a new unit — the Superblock — where motorised mobility is severely restricted and the space is converted for pedestrian, cycling and community use. This has resulted in streets becoming living spaces, with the introduction of urban greenery, flexible street furniture, vegetable gardens, play areas and places for socialising. This approach has brought significant benefits, including reduced pollution, increased social interaction and physical activity, and a revival of local commerce. However, the real value of Superblocks lies in their ability to transform existing urban areas without the need for demolition or significant investment, thanks to their modular, adaptable and replicable design (tactical urbanism). They are a true urban and territorial innovation tool that combines ecological, social and economic dimensions (Nakajima & Murayama, 2024). They are a concrete example of how cities can regenerate by integrating sustainable mobility, green infrastructure, and civic participation. Superblocks demonstrate how urban spaces can be used in healthier, fairer and more liveable ways, and represent one of the most promising trajectories for future cities. The superblock of Barcelona is also interesting because it intervenes on an urban fabric that had been designed in the modern era and constitutes an example of a very famous and imitated urban grid (at different scales) in many European cities and beyond. It is the demonstration that urban regeneration can start without large infrastructures, working within the scope of local urban design, as also demonstrated by the various experiences of Gehl (2010). The concept of proximity, understood as the effective densification of functions and opportunities in urban contexts, is central to overcoming spatial segregation and promoting social cohesion. Models such as the 15-minute city (Moreno, 2024exemplify urban regeneration approaches that prioritise proximity in planning, encouraging functional diversity, pedestrian accessibility, and soft mobility (Carra et al., 2021). On the other hand, the ET2050 scenario developed by the ESPON programme represents one of the most advanced visions for a sustainable and polycentric future for urban Europe. A central theme of the project is the integration of cities and rural areas, which is understood as overcoming the historical opposition between centre and periphery and urban vs rural. The proposed model aims to strengthen the functional relationships between urban and rural areas by promoting the development of integrated urban-rural regions that can share services, green infrastructure, natural resources, and innovation (Bianconi et al., 2018; Pellecchia et al., 2019). The ET2050 vision is based on the idea of complementarity: cities are no longer viewed as isolated entities, but as nodes in a network of smart, resilient and productive territories. This is accompanied by the concept of 'European eco-regions': territories combining energy autonomy, environmental sustainability and a high quality of life, which enhance local economies, agri-food chains and slow tourism. In this context, rural areas are not marginal domains but central players in the ecological transition process thanks to a planning approach that promotes multi-level governance, efficient land use, accessibility, and territorial equity. Ultimately, ET2050 offers us a model of integrated, polycentric development where innovation and cohesion are key tools for addressing 21(st)-century climate, social and economic challenges.

2. Sustainable innovation as an enabling process

In contemporary debates on urban regeneration, territorial innovation is emerging as a strategic tool for addressing environmental, social, and economic urban challenges in an integrated way. It is not merely a

technological vector, but rather a transformative, systemic process rooted in local knowledge, relational proximity, and institutional embeddedness (Oh et al., 2024). The capacity to respond to current environmental challenges in relation to sustainable innovation is a multidimensional topic of growing interest to many scholars of technical disciplines, urban planning and territorial governance (Alberti, 2018; Boons & McMeekin, 2019).
Although territorial innovation is often associated with technological development, a broader, more systemic interpretation links it to a process that is grounded in local contexts and relational proximity, and that has the capacity to generate shared value (Cooke, 2011).
In this context, scientific research has increasingly addressed desirable innovation, i.e. components focused on sustainability (Barbieri et al., 2020), systemic transitions (Markard et al., 2012; Köhler et al., 2019; Branco et al., 2024), and the sectoralisation of impacts towards innovation aimed mainly at economic growth and territorial competitiveness (Edler & Boon, 2018).
As highlighted by Asheim & Coenen (2005), innovation is not an abstract or transferable input, but a socially and territorially embedded phenomenon, shaped by learning dynamics and the proximity between actors, institutions, and place-based knowledge. In this sense, the urban and regional space is not a passive geographical container, but a relational space in which interactions, shared values, and co-production processes generate new forms of value. More recently, scholars such as La Foresta (2021) have argued that the innovative potential of a territory is primarily determined by its human capital intensity, the presence of knowledge-intensive activities, and the capacity to foster institutional coordination and socio-economic integration. Innovation is therefore the result of a complex interplay between tangible and intangible resources, local capacities, and shared strategic visions. In urban contexts, sustainable innovation emerges from the interconnection of multiple systems: governance, education, culture, mobility, health, energy, and the environment. It implies a capacity for adaptive learning and inclusive transformation, enabling territories to respond dynamically to complex challenges such as climate change, demographic transitions, and economic polarization. Importantly, innovation today is seen as the engine of territorial regeneration, capable of triggering endogenous development and collective well-being. This shift is reflected in contemporary planning models which embrace participatory, place-based, and multilevel approaches. As underlined by De Falco (2017), a key condition for effective territorial innovation lies in the co-construction of meaning and value, involving citizens, institutions, and economic actors in shared visions of sustainable development. This objective can be pursued through technological innovation (including digital innovation) and retro-innovation (Bauman, 2020), following the example of natural co-evolutionary processes (Gould & Vrba, 2008). This involves developing strategies and plans to regenerate urban-rural functions, natural eco-structures and welfare service networks. Innovation is therefore a key factor in the ecological transition and the driving force behind a new territorial development paradigm that is increasingly recognised as critical to territorial competitiveness, social cohesion, and environmental sustainability. Innovation is a method and an objective of regenerative planning, restructuring territorial dynamics to create resilient, inclusive and liveable cities and regions (De Bonis et al., 2014). In this sense, innovation and regeneration are two interdependent dimensions of the same transformative paradigm. Urban regeneration is no longer simply a matter of redevelopment or environmental remediation; it must be based on an integrated, adaptive vision of change capable of articulating the material, social and symbolic dimensions. Urban regeneration centred on sustainable innovation cannot ignore the need for a paradigm shift from sectoral, growth-centred approaches to systemic, place-based, participatory, well-being-oriented strategies. Regenerated cities are not merely 'renewed cities', but places that enable proximity, nature and community to coexist in dynamic balance.

3. Toward new urban models of sustainability

Numerous case studies confirm the effectiveness of territorial innovation as a regenerative strategy that addresses urban challenges in a systemic and place-based manner (Moraci et al., 2024). In urban areas,

innovation is no longer a top-down or sector-specific process, but an integrated, participatory, place-based approach that activates latent territorial capital and promotes new models of sustainable urban development. Notably, the green dimension — understood not only as an environmental element, but also as true biophilic, relational and symbolic infrastructure — is emerging as a key driver in contemporary regeneration processes. The Hafen City project in Hamburg is one of the most emblematic urban regeneration projects in terms of environmental and infrastructural aspects. Here, urban design incorporates open public spaces, linear parks and green solutions along the waterfront to combine sustainability, environmental quality and urban attractiveness. Greenery links architecture and landscape, residential, cultural and productive functions, and contributes to redefining the identity of a strategic part of the post-industrial city (Scaffidi, 2024).

Similarly, Barcelona's new urban plan, with its Superillas Verdes (Green Superblocks) project, proposes radically restructuring the existing urban fabric through widespread pedestrianisation, de-impermeabilisation and the addition of micro-parks, urban gardens and ecological corridors. This approach places greenery at the heart of strategies for public health, climate resilience and social innovation. In Paris, the new metropolitan plan (Métropole du Grand Paris) promotes a systemic vision in which greenery forms a network of connective infrastructure capable of generating ecological continuity between the city centre and the suburbs. Projects such as the Parc des Hauteurs in Bagnolet and the Bois Habité in Montreuil demonstrate how green strategies can stimulate regeneration in vulnerable neighbourhoods by introducing nature-based solutions and urban ecosystem services.

Amsterdam is also notable for integrating greenery into regeneration processes with a particular focus on the multifunctionality of public spaces. The Rainproof plan and new neighbourhoods such as Buiksloterham combine environmental sustainability, water resilience, and architectural innovation. This demonstrates how green and water management can be integrated into urban morphology through circular and adaptive approaches.

Finland is also an interesting case of regenerative urban planning and circular transition. The city of Lahti, located in southern Finland, was awarded the title of European Green Capital in 2021 thanks to an integrated urban and territorial sustainability strategy that combines digitalisation, the circular economy and active citizen participation. Lahti is now an advanced model of urban co-creation, where the interface between city and countryside is interpreted as a dynamic space for environmental and social innovation. The city's strategic plan is based on a number of key transformative levers: (1) Digital tools & smart monitoring: through the use of digital applications such as CitiCAP (citizen's cap and trade platform), citizens monitor their carbon footprint from daily travel and receive incentives for virtuous behaviour. Technology thus becomes a tool for environmental awareness and individual action; (2) Circular economy & zero-waste policies: Lahti actively promotes circular economy models in various sectors, from waste treatment to industrial production. The Kujala Waste Centre ecological district is one of Europe's most advanced hubs for material recovery, recycling and reuse; (3) Citizen participation & urban-rural nexus: local planning is based on co-design practices that actively involve local communities in setting environmental goals and designing shared solutions. In particular, neighbourhood workshops and educational programmes are set up to strengthen the link between green spaces, urban agriculture and sustainable practices. Taken together, these cases demonstrate that localized innovation is not peripheral to mainstream urban agendas, but rather central to the ecological transition (Sgambati, 2022). They highlight how spatial planning, when combined with participatory governance and territorial intelligence, can guide transformative processes that are adaptive, just, and regenerative.

4. City and green spaces: the biophilic perspective

Moving beyond the framework of biophilic design (Beatley, 2016), regenerative urbanism must embrace territorial intelligence, defined as the capacity of a territory to mobilize and integrate resources, networks, and knowledge towards shared goals of sustainability and well-being (De Falco, 2017). Territorial intelligence

fosters the emergence of resilient ecosystems where ecosystem services, social equity and economic innovation converge.

A more radical approach to the relationship between greenery and cities is expressed through the themes of 'nature in the city' and 'the city in the garden'. This movement of thought and set of practices can be defined as 'biophilic cities' (Lefosse et al., 2023). The biophilic approach is essentially philosophical, presupposing respect for all life forms and care for the connections and co-evolutionary relationships between multiple ecosystems. The aim is to move beyond an anthropocentric view of our relationship with nature. Supported by the theory of biophilia (Kellert and Wilson, 1993), biophilic design aims to strengthen the connection between humans and nature to improve human health, well-being, and quality of life. Logically, at the territorial scale, biophilic urban planning proposes the reconciliation of human beings with nature on physical, mental, and social levels (Bathri & Kasliwal, 2019). The biophilic approach to designing built spaces begins at the level of individual buildings and is initially characterised as a specialised branch of architectural design (Zari, 2018). It is accompanied by the biomimetic approach, which involves using technologies inspired by the solutions adopted by plants and animals in nature. This incorporates the natural evolutionary process into the conception of the form and functionality of objects, methods, and tools.

Biophilic design, initially a component of urban design at the neighbourhood or city level (Thomson and Newman, 2021), has recently evolved into a global conception of urban space and the principles that should underpin its development. The biophilic approach revisits the theme of place as a key factor in sustainability, albeit in a different way, even in the absence of explicit configurational or morphological choices regarding settlement forms. This highlights a recurring theme in the rhetoric of the biophilic city and its limitations in our discourse: an initial indifference to urban forms and the belief that widespread biophilic greening initiatives can give every urban space a biophilic character. However, 'biophilic' elements are employed at various geographical scales, including urban parks, green corridors, urban farms and green streets. This forms a set of solutions that reintroduces the relationship between urban morphology and green space.

Biophilic urban planning (Beatley, 2011) is considered an advantageous solution for addressing the challenges of both climate change and economic development. It provides a set of techniques and devices that are useful for tackling specific issues, such as urban heat islands and particulate reduction. Furthermore, it acts as a model for a new, more productive way of designing cities. However, this aspiration can lead to the creation of environments whose construction and management are expensive, which is potentially in conflict with the objective of ensuring access to 'natural' spaces — one of the fundamental principles of this line of research and application. The sophisticated use of green materials in urban construction also risks becoming a form of urban and real estate development that supports eco-gentrification processes.

In his 2016 handbook, Beatley set out the basis for the evolution of Green Urbanism into Biophilic Urbanism, using Singapore as a prime example of the shift from a conventional 'garden or green city' to a biophilic 'city in a garden' (Beatley and Newman, 2013) then made the latest advance in biophilic urban planning by extending it to a bioregional scale to emphasise its contribution to making cities more resilient while improving social and natural capital (Newman et al., 2017).

In terms of urban form, it seems that biophilic urban planning is moving towards polycentric structures rather than reproducing the highly compact settlement models that are typical of eco-cities or certain other New Urbanism experiments. The case of Singapore is illuminating here again: the city's territorial master plan openly and explicitly chooses the polycentric model, integrating various infrastructure levels and basing the urban design's underlying structure on the urban ecological network. This recovers the original ideas of environmental planning to some extent; as mentioned at the beginning of this article, these ideas were based on the concept of a green network of parks as a structuring element of the urban landscape.

This Special Issue invited scholars to investigate this integrated paradigm through diverse disciplinary lenses—urban planning, geography, design, environmental science, and regional studies—exploring how morphological

analysis, green infrastructure planning, and innovation ecosystems can jointly contribute to the transition towards new urban and territorial models.

5. Overview of collected contributions

The contributions presented in this Special Issue reveal an emerging paradigm of human settlement where eco-environmental systems function as integrated protective frameworks for vulnerable urban populations while forming networks that enhance safety and livability through strategic integration with existing urban infrastructures. This collection demonstrates how contemporary urban challenges demand innovative approaches that simultaneously address social equity, environmental resilience, and spatial transformation through the lens of regenerative urbanism.

The assembled papers explore diverse yet interconnected themes that collectively illustrate this paradigm shift. Social inequalities rooted in settlement patterns are examined through the lens of the revitalizing potential of university campuses in European contexts, including Sarzano and Ferrol (Prado-Acebo & Río Vázquez, 2025). The co-design of spatial and social infrastructures emerges as a critical methodology for creating more inclusive urban environments (Contato & Ronsivalle, 2025).

Several contributions focus on regenerative urban models, particularly examining how Positive Energy Districts represent a fundamental paradigm shift in sustainable development (Pidalà, 2025), and how the restoration of Mediterranean urban rivers, exemplified by the Guadalmedina in Malaga, can create vital ecological corridors within dense urban contexts (Mora-Esteban et al., 2025). The research also addresses the unique challenges facing historic urban forms, as demonstrated through studies of ancient cities like Viterbo (Errigo & Iva, 2025), while presenting innovative assessment tools for urban greenery health specifically adapted to Mediterranean climatic conditions (Sanfilippo et al., 2025).

The case studies span diverse geographical and typological contexts: from the adaptive reuse of former military sites in Cagliari (Colavitti et al., 2025) to Seoul's ambitious vision for infrastructural renaturalization (Canessa et al., 2025), from the transformative potential of bicycle infrastructure networks in urban redesign (Centanaro & Sommariva, 2025) to new methodological frameworks for understanding both the intrinsic qualities and network properties of urban green spaces (Cutini & Mara, 2025). Together, these contributions provide a comprehensive foundation for reimagining urban settlements as integrated socio-ecological systems.

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Green and revitalised cities through universities: Sarzano and Ferrol campus

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Abstract
Education is a topic of global interest in all areas, including the spaces where it takes place. However, although there is talk about a change in education and new active methodologies, the space necessary for these new methodologies is not being taken into account.
In this context where there is a need to update learning scenarios, we must take advantage of the opportunity to change university spaces in order to innovate, not only in educational spaces, but in the whole city, as educational centres are an important part of the urban fabric.
In this article we will analyse the importance of green infrastructures, investigate how to carry out the regeneration through the recycling of buildings and the reactivation of the city through the university. All this through two case studies that constitute examples of good practices, the case of the Sarzano campus of the University of Genoa, in Italy, and the Ferrol campus of the University of A Coruña, in Spain, which serve as a reference of innovative experiences that have achieved a good integration between universities, green areas, and the territory, achieving an increase in local environmental, social and economic welfare.

Keywords
University; Campus; Green infrastructures; Recycling of buildings; Reactivation of the city

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1. Introduction

Education is a topic of global interest in all areas, including the spaces where it takes place. However, although there is talk about a change in education and new active methodologies, the space necessary for these new methodologies is not being considered. And the space in which learning takes place has not changed in the last century, or not substantially (Prado-Acebo, 2024). In this context where there is a need to update learning scenarios, we must take advantage of the opportunity to change these university spaces to innovate, not only in educational spaces, but in the whole city, as educational centres are an important part of the urban fabric. Thus, the need to change educational spatial systems must be approached in an innovative way, taking into account relevant issues such as green infrastructures, as "university-community partnerships can play an important role in this green infrastructure maintenance issue" (Gerlak et al., 2022, p. 393-394), or how universities can reactivate cities and shape urban form, constituting models of regenerative cities; thus creating places capable of constantly renewing their resources, boosting the prosperity of citizens, protecting the environment, developing the local economy, and enhancing both the social and cultural life of their inhabitants. The form of a city can affect its sustainability, as there exists a relationship between the shape, size, density and uses of a city and its sustainability (Burton et al., 2013, p. 1), and the university plays a key role as developer of the city (Perry & Wiewel, 2015, p. 3), so the design of green infrastructure and urban greenery have become a central tool for enhancing not only environmental and ecological value, but also psychological well-being, social aggregation, services and quality of life within cities (Tucci, 2023, p. 91). "Innovation represents a critical factor in the process of transition towards greater environmental sustainability, the driving force for a new development paradigm and a new mechanism of evolution based on experimentation in design processes" (Tucci & Ratti, 2022, p. 191; Lombardini et al., 2023, p.213). Therefore, planners and designers, who have always played a central role in the creation and development of vital and liveable cities (Diepen, 2002, p. 93), must should plan the urban fabric by addressing these issues. In this article we will analyse the importance of green infrastructures, openness and contact with nature within the spatial structures of universities, producing a symbiosis with the environment, preserving natural resources, and making them available to the entire community, as these are not only public universities, but also spaces open to the entire population. We will also investigate how to carry out regeneration through the recycling of buildings and the reactivation of the city through the university, with a spatial arrangement of the universities integrated into the city, with their corresponding green areas at the service of the community, in order to achieve the multifunctionality of these spaces, which should be not only educational, but also for recreation and for the enjoyment of the entire urban environment. Likewise we will study a couple of examples of good practices, showing the history and design of two international case studies between which parallelisms could be drawn, such as the Sarzano campus of the University of Genoa, in Italy, and the Ferrol campus of the University of A Coruña, in Spain, which serve as a reference of innovative experiences that have achieved a good integration between universities, green areas, and the territory, achieving an increase in local environmental, social and economic welfare.

2. Two case studies as examples of good practices: Sarzano's Campus, UNIGE (IT) and the Ferrol's Campus, UDC (ES).

The study of the importance of green infrastructures in universities and cities, the recycling of buildings as a tool for the regeneration of cities and the reactivation of cities through universities, will be carried out through the thread of two case studies, which serve as examples of good practices, Sarzano's Campus of the University of Genoa in Italy and the Ferrol's Campus of the University of A Coruña in Spain. The Università degli Studi di Genova (University of Genoa, UNIGE), founded in 1481, is scattered throughout the city, still growing through the city today. However, it is possible to point out three main and clearly differentiated poles, which are the

historical pole in Balbi, the medical, scientific and technical pole in San Martino, and the new pole in the historical centre in Sarzano, which is the one we are going to pay more attention to, as this is where the Department of Architecture and Design is located, and where we can observe both green infrastructures, such as the recycling of construction, and the integration and reactivation of the area. The Department of Architecture and Design (DAD) stands on Castello Hill, in the oldest part of the historic centre of Genoa, the site of the ancient convent of San Silvestro. Despite a previous project, the DAD was not moved to Sarzano until the San Martino pole became too small (Decri & Russo, 2021m). The decision to relocate to the old town met with opposition but proved to be a success and one of the most interesting cases of revitalisation of an old quarter in a European city (Ricci & Schroeder, 2010, p. 55). In contrast to this Italian case, there is the Spanish case of the Ferrol campus of the Universidade da Coruña (University of A Coruña, UDC), where, among other schools, the EUDI (Escuela Universitaria de Diseño Industrial, University School of Industrial Design) is based. The Ferrol industrial campus, located in the Esteiro neighbourhood, is an example of green infrastructure, as well as of recycled construction integrated into the urban area, reactivating it. It was originally a hospital, which after suffering a fire was rebuilt using the Tollet system, creating the pavilions hospital of Esteiro. It consisted of 4 main pavilions (General Services, Medicine, Surgery and Venereal), 2 medium ones (Contagious and Prisoners), 5 smaller ones (Washing rooms, Operating theatres, Insane, Cadaver Deposit and the Apothecary), and a series of complementary spaces (Soraluce Blond, 1996, p. 116-118). Of all these, only the four main pavilions and one medium-sized one (the prisoners' pavilion) remain, the other pavilions having been demolished or replaced by more modern buildings. It is in one of the main pavilions that the EUDI is now located.

3. The importance of green infrastructures in the universities

To begin with the importance of green infrastructures in universities, we must take into account the openness of learning scenarios (both from the perspective of the audience admitted with the corresponding openness to the community and from the perspective of the physical boundary), as well as their contact with nature, for the correct development of the teaching-learning process. "Come, always come! The walls of a school should be made of glass, it has been said, and quite rightly so; they should be made of glass so that everyone can see what is going on inside: the parents because inside are their children and the people and the state, because those children will be citizens tomorrow" (Pizzurno, 1890, p. 600, as cited in Toranzo, 2020, p. 34). Using the fact that everyone sees everything as a mechanism of social transparency (Pozo Bernal, 2017, p. 234). These words could serve as a manifesto, as they clearly express the idea pursued through the opening of classrooms and educational centres. Thus it will be necessary to consider issues such as the dissolution of the boundary, transparency, visual continuity, spatial continuity, flexibility, openness and nature. Indeed, nature and interaction with the environment are a key factor in human development. Connecting people, living in cities, with urban nature is necessary, as people are biophilic and contact with nature has physical and emotional benefits (Beatley, 2016, p. 79). Green infrastructures in urban areas bring public health benefits (Sommariva et al., 2022, p. 155-156), green spaces provide a context to facilitate social interaction on campus, building a sense of place and community, bolstering student health and resilience (Walshe & Law, 2022, p. 979-980), and them could even be considered a therapeutic green (Tucci, 2023, p. 92). The opportunity to connect with nature is ubiquitous and it must be taken (Beatley, 2016, p. 79-80), and not only projecting green belts, but also ensuring the access to green space (Burton et al., 2013, p. 25, p. 35), so its necessary a re-appropriation of urban spaces by nature, and the integration of greenery in the urban environment has become one of the main objectives of development strategies in European community programmes (Tucci, 2023, p. 92). Gardens and parks are excellent learning spaces (Hertzberger, 2008, p. 245), since Rousseau already indicated that the best school is the shade of a tree, implying that the best school was in the open air, in nature, and not within the walls of a building. But, as Viñao points out, once the need for the architectural

work was accepted, the schoolyard or school field signified the presence of nature within the educational centre. And it is not only necessary to go out into it, outside, but also to incorporate it (Viñao, 1993-1994, p. 34), associating these green spaces with the active methodologies that are intended to be encouraged in today's learning scenarios. The open-air classrooms took as their starting point one of the needs of the educational centres, the extension of the limits of the classroom and access to the outside, in order to develop the teaching-learning process and its activities in the open air. Although they did not last for long and this model did not become established, it is worth highlighting the capacity of outdoor schools to experiment, breaking with existing models and proposing new alternatives. There are numerous actions in which attempts have been made to open the doors and even demolish the walls of the classrooms, and history repeats itself, "although the old master Wright had already led the research on the opening of the box, we went back to it" (Asensio-Wandosell et al., 2014, p. 21), it seems that not only history, but also architecture, are cyclical. In the cases taken as a reference, the importance attributed to green areas stands out. At this point, we must emphasise the original Latin or Mediterranean meaning of the word school, thus, going back to its etymological origin, we observe that school comes from the Latin schola, and this from the Greek σχολη scholé, which means leisure or free time (RAE, 2022), for which recreation and gardens played a primordial role. And if there is a single term that seems to capture the essence of green university infrastructures, it was and remains the term campus, the Latin word for field (Perry & Wiewel, 2015, p. 7). However, in contrast to the American campus, the selected case studies do not imply a university community separated from the city, but rather integrated with it. On the Sarzano campus, its spaces and classrooms are mainly enclosed, however, the inner courtyard and its gardens create that openness and contact with nature. The hanging garden of the nuns of San Silvestre, also known as the roof garden, is part of the monastery and it took many years, several projects and several attempts to create it (Decri & Russo, 2021i). The Ferrol campus also has mostly enclosed spaces, although in some of its centres, such as the EUDI, the intermediate spaces have an open and wide character, which allows them to be used as meeting areas, and has some flexible classrooms with a transparent boundary; and it is located in a privileged space, since connecting all the buildings of the campus, we can observe a garden, which is in addition a botanical garden, and which also creates this openness and contact with nature. Among the abundant open spaces on the Ferrol campus, the central green area is particularly noteworthy, which serves as an agora and a pedestrian meeting place. This open space can be interpreted as the result of the opening of the different educational centres towards a common place, caused by the action of the configuration and layout of the campus (Universidade da Coruña, 2009, p. 148), which encourages interaction and connection between them. In the same way, the gardens of the Ferrol campus make it a campus with a strong presence of nature, recovering that original meaning, which allows us to enjoy the gardens and the privileged environment of the schools and colleges that make up the campus. We can even speak of the garden or nature, in a double dimension, firstly, because it is incorporated within the campus and buildings themselves, and secondly, because the university expands and extends outwards, colonising all the spaces that surround it.

4. Recycle to regenerate

The urban recycling paradigm could be defined as a space of coexistence between new classrooms and architectural heritage. This scenario consists of a combination of past and future, in which identity and heritage are mixed with novelty, combining memory and innovation. There is a multitude of educational spaces that "have not been built with the purpose for which they were intended" (Sarmiento, 2020, p. 13), and the fact is that taking advantage of existing architecture is something that has been done since the beginnings of the university. This same recycling situation can be found on the Sarzano campus of the UNIGE, along with most of the faculties and schools of this Italian university, located in former monasteries and palaces. Another example could be the complex of the Esteiro campus of the UDC, which used to be a former hospital. Although

this practice is carried out in many countries and cities around the world, the Mediterranean area, and more specifically Italy, is an example that should be highlighted. The University of Genoa is scattered throughout the city of the same name, in ancient and majestic palaces, churches and various buildings with a strong historical component. The Faculty of Architecture and Design occupies a former convent, used between the 15th and 19th centuries by the Dominican nuns of Pisa (Decri & Russo, 2021e; Decri & Russo, 2021m). One of these Genoese streets, via Balbi, also stands out, where in the same block we can find four ancient palaces that today are the seat of different faculties of humanistic sciences, namely letters and philosophy in Balbi 2, 4 and 6, and jurisprudence in Balbi 5. Thus, while it is an opportunity to build a new building from scratch for teaching purposes, it is also an opportunity to recycle a building with a great historical character and great heritage value to convert it into a university building. Each has its advantages and disadvantages, which we are not going to mention here since, in any case, the recycling of buildings is a situation that usually occurs, and this circumstance should be taken advantage of, adapting its interior as far as possible, to make it a valuable setting for learning. The fact is that architecture has an impact on the way we learn, and in the case of these large inherited constructions, just the building itself has a formal impact. As the Department of Architecture and Design works within the concepts and formalisms, beauty and aesthetics are explored in part thanks to the invitation of the space where they are studying, which serves as an example. In addition to the direct advantages of learning in such a space, the recycling of space also provides economic advantages. Thus, according to the Ministry of Education, the knowledge-based economy presents an opportunity to revitalise obsolete heritage buildings. And especially in times of crisis, universities should consider as a priority the strategy of using old buildings rather than building new ones. It is clear that state-of-the-art laboratories are more difficult to integrate into old buildings due to security restrictions and very specific technical requirements. However, more flexible activities can easily be adapted to historical buildings of cultural and industrial heritage with specific local character and significance in the city. These symbolic buildings, which are found in many European university cities, can contribute to creating inspiring learning scenarios and strengthen the position of European universities in the global competition to attract the best students, professors and researchers. Thus, giving new life to old buildings may be the key to the campus of the future (Ministerio de Educación, 2011, p. 83). And in order to adapt the heritage to the necessary learning scenarios, "the university must act combining respect and progress, by recovering pre-existing structures in order to adapt them to the new use. By proceeding in this way, it will be able to benefit from a quality consubstantial to any monumental piece, which is its living character in time" (Campos Calvo-Sotelo, 2017, p. 327). Thus, monuments and the historic urban fabric act as containers for university uses, encouraging the culture of reuse in university buildings or urban recycling. In all these cases of urban recycling, it has been necessary to carry out various works to adapt these ancient architectural complexes to the different needs and programmes required by the evolution of university institutions. Broadly speaking, two main approaches have been followed. On the one hand, the aim has been to adapt historic buildings originally designed for specific university purposes so that they can meet the new missions and demands of these constantly evolving institutions. On the other hand, the recovery of buildings that had completely different functions has been carried out, transforming them for their use as university spaces for the teaching-learning process and for research (Clemente & Ibáñez, 1995, p. 192-193), with this second model corresponding to the two selected case studies, which reflect the historical and cultural diversity of the educational institutions, merging the architectural legacy with the contemporary needs of the university.

5. The reactivation of the city through the university

And not only do we find these new recycled spaces, but we must also highlight the reactivation of the city through the integration of the university in the environment, blurring the boundaries between both, creating a link within them, and thus moving from the university to the city, achieving openness to the community.

The different schools and departments of UNIGE are housed in recycled buildings and are integrated into the city with the aim of reactivating the city. It may seem curious, for example, that the universities do not have basic services such as a cafeteria or reprography, however, this is a strategy to stimulate the city, using all the establishments, restaurants and shops that are in the vicinity of the schools and surrounding them, so that university life is not limited to the university campus, but expands throughout the city, since the various schools are scattered throughout the city and we are therefore talking about a campus city. The enormous potential of the universities for city revitalization must be considered, not only through their influence as institutions but also via the purchasing power of students and the broader academic community, which generates demand for goods and services. In recent years, many universities have chosen to live together with their community rather than live apart from it. This approach aligns with Dewey's philosophy that education and society are intrinsically connected, positioning universities as catalysts for positive transformation within their local environments (Cisneros, 1995, p. 11-24). According to Magnani, the aim is for the city to be reflected in the university, and to achieve this concept, UNIGE manages an important part of the city's great real estate heritage, so that there is a close link between the historic university buildings and the urban dimension of Genoa. In this way, the aim is not only to reflect the urban dimension of Genoa in the historic university buildings, proposing an itinerary through the interesting material testimonies of a cultural heritage that extends over the centuries, but also to offer a wide panorama of the knowledge and know-how of the city. The aim is therefore to open up the university buildings to the city, with all their problems, but also with their potential as elements fully integrated into Genoa's history and current affairs (Magnani, 2015). The city of Genoa has at its core the university division of functions into clusters, which thereby relate to the city. The humanities universities located on Via Balbi are housed in prestigious buildings within the historic fabric of the city, and the relocation of the Department of Architecture to Sarzano Hill has helped to recover this territory. In this way, it is possible that the relocation of the School of Engineering to Erzelli will allow the formation of a strong and viable cluster, however, it is necessary that the connections and the surrounding fabric are able to absorb the energy of a new pole. At this point it is interesting to appreciate the constant relationship that could be established between the city and the universities in the planning of their growth, since synchronising and moving from the university to the city creates multiple benefits for the citizens (Ricci, and Schroeder, 2010, p. 47). Thus, in the metropolitan area of Genoa a linear university settlement system is emerging within the urbanised territory, as the progressive creation of new scientific clusters is creating new central areas in the city, in which around them the urban functions change and increase, raising their rank (Ricci, and Schroeder, 2010, p. 35). Furthermore, this system is centred around a possible long public transport line, although it is currently uninterrupted, which would connect the four urban nodes that can be considered urban regeneration poles. The first pole is the Erzelli area, where it is proposed to locate the Politecnico, a centre for technological and engineering education, next to Genoa's international airport, the Cornigliano train station and the coastal motorway node. The second pole is via Balbi, which contains the main area of the University. The third pole refers to the complex of the Department of Architecture in the historic centre district, in Sarzano. And the fourth pole refers to the Schools of Medicine and Science in San Martino (Ricci & Schroeder, 2010, p. 36). Thus, the city as university is a European model, according to Ricci and Schroeder, it should also be addressed in the ongoing debates. The current shapes and images of dispersed or diffuse urban landscapes, through the urban occupation of almost all parts of the territory, are obstructing a truly urban conception of the university, transcending the intra-urban or peri-urban models of the past. And the university's potential as a catalyst for the development of surrounding areas or as a connecting element, through the creation of new spatial and mobility networks, within dispersed territories is systematically underestimated. The knowledge society clearly encourages the university to be considered as important as industrial or transport issues in urban development. The constraints and spatial density of the Genoa case study, coupled with the scale of the Ligurian coast as an urban landscape and the size of its university, suggest a conception of a different

type of university. Thus, the opening of campuses and the creation of new interrelationships combine the economic advantages of integrating the university into urban development with the improvement of neighbourhoods, post-industrial sites and the overall quality of the environment (Ricci & Schroeder, 2010, p. 24-25). In short, within the opening up of learning scenarios, we have already seen that it is not only a matter of creating open spaces and favouring transparency between learning scenarios, but also of opening up to the community, through spaces accessible to all people, creating links between the university and its surroundings, moving from the closed enclosure of the university to the city (Prado-Acebo, 2024).

6. Analysis and comparison of the two case studies

Focusing on our two case studies, Sarzano's Campus of the University of Genoa in Italy and the Ferrol's Campus of the University of A Coruña in Spain, it is possible to observe how both cases respond to the urban recycling paradigm, conserving the exteriors and reconditioning or rehabilitating the interior, also producing the transition from the university to the city, as the university is dispersed throughout the urban area, integrating and re-activating the city. In both case studies, the classrooms are still very traditional, and the spaces are fundamentally enclosed. However, in the DAD, the interior courtyard and its gardens stand out, creating an openness and contact with nature. In the EUDI, the privileged space in which it is located, the campus, because connecting all the buildings there is also a garden. The diversity of spaces in both universities could be improved, as they are mainly traditional classrooms, although they are located in privileged places. It is fascinating to observe the historical component of the UNIGE, as well as to admire the art that invades walls, ceilings and, in short, surrounds all the rooms, or the historical value of the Ferrol campus and enjoy its gardens. In the case of the DAD, the classrooms are located in a former convent, like many other UNIGE locations that use old palaces, monasteries, churches and various historical constructions, recycling buildings, where in some of them the building and its exterior facades are preserved, having been rehabilitated inside, while in many others both the exterior and the interior of the original work are preserved, thus finding classrooms with frescoes on the ceilings and walls full of works of art. However, both in the EUDI and in most of the buildings on the Ferrol campus, only the exterior of the pavilions of the old hospital have been preserved, which have been refurbished to house the classrooms and halls in which the university is located, accompanied by new constructions on the same site. The Sarzano campus is notable for its inner courtyard and gardens, which create an openness and contact with nature. As well as the botanical garden that connects all the centres on the Ferrol campus, a large green space that encourages interaction and connection. Moreover, in this way, the learning scenarios are expanded throughout the Ferrol campus, open to the city, encouraging interaction with it. In the same manner as happens in the DAD, which benefits from the services that surround it, reactivating the city through its educational centres scattered throughout the city. Thus, thanks to the fact of sharing resources and infrastructures, it is possible to avoid unnecessary, absurd and costly duplication in certain facilities that both the university and the city can use in a coordinated manner. This allows for a more efficient return on investment, especially in sports facilities, auditoriums and other spaces that can benefit both communities (Universidade da Coruña, 2009, p. 58). Furthermore, this collaboration contributes to strengthening the links between the university and the city, creating a closer and more mutually beneficial relationship. However, while in UNIGE the university is dispersed throughout the city of Genoa, the UDC has the peculiarity of being dispersed not only throughout the city but also throughout the territory of A Coruña, with its various campuses in Coruña and the centre located in Ferrol, on which we are focusing. Taking all these issues into account, it could be said that both universities are located in privileged places, so it is fascinating to observe the historical component that is breathed in the Sarzano campus, as well as to admire the art that invades walls, ceilings and, in short, surrounds all the rooms, or the historical value of the Ferrol campus and enjoy its gardens. In conclusion, it is possible to observe the parallelisms between both case studies, reinforcing the established paradigms, especially regarding the importance of the garden, green areas

and contact with nature, urban recycling as a tool for the regeneration of cities, and the reactivation of cities through the strategic location of universities, blurring the boundaries between the two of them to transform the learning scenarios from the university to the city.

Fig.1 DAD (Deparment of Architecture and Design), Sarzano Campus, University of Genoa, Italy

Fig.2 EUDI (University School of Industrial Design), Ferrol Campus, University of A Coruña, Spain

Fig.3 Sarzano Campus Garden, University of Genoa, Italy

Fig.4 Ferrol Campus Garden, University of A Coruña, Spain

Fig.5 Sarzano and Ferrol campus as a green infrastructure in relation to the cities of Genoa and Ferrol

7. Conclusions

This research is based on education as a topic of global interest, and specifically on one of the spaces where it is developed, the universities. These learning scenarios need to be updated, and the opportunity to change these university spaces must be taken in order to innovate, not only in educational spaces, but also in the whole city, as educational centres constitute an important part of the urban fabric and allow the development of integrated strategies that innovatively address green infrastructures, the reactivation of cities and the configuration of urban form, constituting models of regenerative cities.

This document aims to highlight the importance and potential of universities as a mechanism through which to achieve innovation, the inclusion of green infrastructures and the regeneration of cities, as educational centres are a fundamental element for the progress of society and are a basic design resource for shaping urban form. Two examples of good practices have been presented, such as the Sarzano campus of the University of Genoa, in Italy, and the Ferrol campus of the University of A Coruña, in Spain. These case studies allow us to observe the role of the university in incorporating green infrastructures on campus, which are crucial for the development of students, and whose benefit and enjoyment extends to the whole community; as well as recycling buildings to regenerate value by giving new life to historical heritage, with the multiple advantages that this entails; and reactivating or revitalising the city through the university and the consequent university life. Universities represent a rather critical challenge at the urban level, however, they can constitute an interesting case study for developing integrated strategies to address these issues (Costa & Delponte, 2024, p. 33), and serve, like the cases presented, as a reference of innovative experiences that have achieved a

good integration between universities, green areas, and the territory, achieving an increase in local environmental, social and economic well-being. Universities, which are often conceptualised as small cities, and which play a role in environmental sustainability, have a responsibility to lead society towards a sustainable future. Moreover, nowadays, universities all over the world want to set an example with their environmentalist approaches, sustainable activities, academic achievements (Altun & Zencirkıran, 2023, p. 425-426), green infrastructures and learning scenarios that bring added value to the city. Ultimately, university planning and all the services associated with it, as well as the opportunities for urban innovation it presents, must be taken into account when drawing up urban strategies.

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Image Sources

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The creative co-design of collective spaces

Two case studies of generating new spatial and social infrastructures

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Abstract
In recent decades, the education of minors has been compromised by high rates of educational poverty, further exacerbated by the COVID-19 pandemic. This situation reduces the effectiveness of social infrastructure – the fourth pillar of infrastructure alongside green, blue, and grey infrastructures – that underpins the welfare of national and local entities and encompasses the spaces and artifacts that host social, cultural, and economic activities.
The "P.arch. Playground per architetti di comunità" project (P.arch. Playground for Community Architects), aimed at addressing educational poverty, has piloted an innovative educational pathway based on creative activities and engagement with territories and communities from an inclusive and regenerative perspective. The P.arch project involved schools in socio-economically fragile contexts in Sicily and Lazio regions, developing four modules, including "Creative Architecture," which enabled students to design public and school spaces. Through these activities, new shared spaces and Community Hubs were created to promote social inclusion and community education. Students acquired both cognitive and non-cognitive skills, contributing to an innovative model of community development.
This contribution, therefore, highlights the importance of educational processes for generating new connections within the social infrastructure system. It aims to demonstrate how active education and youth engagement are essential for addressing educational poverty and fostering social well-being.

Keywords
Co-design; Collective spaces; Urban regeneration; Community Engagement; Cityforming protocol

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1. Introduction

1.1 The Educational Function of Collective Spaces and Co-design

In recent decades, a global context has emerged where cities enhance their communication potential and services for citizens, the issues related to school learning among minors and school dropout rates continue to increase. These factors are closely linked to economic poverty and are more prevalent in contexts with significant socioeconomic lag. Opportunities for educational, physical, and socio-emotional growth are crucial for children and adolescents. For this reason, Save the Children introduced the concept of "educational poverty" in Italy, defined as «the deprivation experienced by children and adolescents of the opportunity to learn, experiment, develop, and freely flourish their abilities» (Save the Children, 2014, p. 4). They also developed the first Educational Poverty Index, based on 14 indicators analysing the accessibility and quality of educational offerings and the levels of minors' participation in recreational and cultural activities.

If the situation was alarming before the COVID-19 pandemic (Save the Children, 2019), today, closures and restrictions have significantly increased the risk of material poverty and generated a significant "learning loss." According to recent studies, globally, the number of children and adolescents in poverty is estimated to have risen from 582 million in 2019 (approximately 32% of the total) to 715 million (38.4%) in 2020. In Italy, according to Save the Children (2022) and ISTAT data on the living conditions of minors (ISTAT, 2023) 1.3 million children live in absolute poverty (compared to 1 million in 2019). More than one in four children is at risk of poverty and social exclusion. Additionally, 67.6% of children under 17 have never gone to a theatre show, 62.8% have never visited an archaeological site, and 49.9% have never entered a museum. Furthermore, 22% have not engaged in sports or physical activities, and only 13.5% of children under three have attended a nursery.

In this scenario, a new educational paradigm is necessary, focusing not only on individual performance but also on social growth and relationships. This paradigm should address the challenge of promoting the development of both cognitive and non-cognitive skills, such as dynamism, cooperation, empathy and openness to culture and experience. It should stimulate complex and critical thinking, strengthen emotional bonds and the development of listening skills and a sense of community, and create conditions conducive to developing artistic and creative abilities.

It is also essential to consider not only the existing dynamics of disadvantage that impact educational poverty but also – if not primarily – to awaken a sense of responsibility towards their territory, city, and neighbourhood, in the younger generation. This approach aims to rebuild a new sense of community and ensure that the community itself becomes the guardian of the local context's material and immaterial qualities.

In this context, the "P.arch. Playground per architetti di comunità" project (P.arch. Playground for Community Architects), research project fits in, aiming to implement strategies to counteract educational poverty through the experimentation of an innovative and replicable educational process based on creative methodologies and active, open, and project-oriented relationships with the territories, with a focus on urban regeneration. Paying particular attention to fragile contexts, the project has promoted strategies to establish stable educational centres in some peripheral areas, positioning the school as a strategic driver of development and change (Gisotti & Masiani, 2024). It supports the school in its role of creating better and more responsible global citizens through collaboration with universities, institutions, and associations, and involving teachers and families to form new educating communities.

The concept of an educating community refers to a group of individuals, institutions, and organizations that collaborate to create an integrated and inclusive educational environment aimed at promoting the learning and development of community members, especially the young. This approach recognizes that education occurs not only in schools but also in families, workplaces, and other social contexts. Therefore, an educating community creates a continuous and integrated learning environment where every interaction and experience

contribute to individual and collective growth, aiming to form responsible, competent, and aware citizens capable of positively contributing to society, to define a new urban humanism (Pultrone, 2014).

The importance of collective spaces has been central to the experimentation, aiming to recover, transmit, and recognize the "sense of community", refers to a feeling of belonging, interconnectedness, and shared responsibility among group members. It involves an emotional and relational bond that strengthens social cohesion and mutual support.

Additionally, the project seeks to define the differences between "space", understood as a physical or geographical entity, and "place", which is considered a socio-cultural entity. These are to be understood as expressions of the society that inhabits them, social spaces where a sense of belonging is recognized, where identity is built. These spaces must be designed with the community, fostering inclusion, social cohesion, and a sense of belonging, and have the capacity to promote and support deep and lasting changes, both tangible and intangible, in the urban environment (Ashwort, 2008).

The identification and design of urban areas for regeneration, to have an educating and empowering function, have been approached in the project as a participatory, collaborative process in which various actors, such as school children, citizens, organizations, public and private entities, work together to conceive, develop, and implement solutions to common problems or challenges.

Fig.1 Schematization of the educational function of collective spaces and the co-design process

1.2 Planning in a social and spatial unequal city. A complex challenge to tackle

The contemporary socio-spatial context has become extremely multifaceted, and therefore, to define an adequate theoretical context for the case study described in this article, it is necessary to consider different topics increasingly relevant and interconnected with each other:

- the relationships between humanity and nature, which provide a backdrop for a renewed approach to humanity's role on the planet;
- how humanity builds 'infrastructures,' understood primarily as artifacts that modify nature and produce impacts on space;
- the role of education as an opportunity to raise awareness regarding the previous topic;
- the role of urban and territorial planning within this complex framework.

The complex relationships between humans and the planet have prompted deeper reflection on humanity's transformative role on Earth. Crutzen & Stoermer (2000) define the Anthropocene as an era where human actions are geologically significant. In contrast, sensitive designers are exploring positive solutions through ecological urbanism, as highlighted by Mostafavi & Doherty (2016), who advocate for new paradigms that foster harmonious interactions with ecological systems. Carta & Ronsivalle (2020) envision a creative Neo-Anthropocene based on symbiosis with nature, while Carta (2024) introduces a holobiontic hypothesis, emphasizing the interconnectedness of individuals and communities within their environments. This perspective underscores that infrastructure should not merely overlay the biosphere but integrate complex social and spatial relations essential for urban environmental quality (Shannon & Smets, 2016).

International organizations now favour a holistic view of infrastructure, as noted in the "Climate Change 2022: Impacts, Adaptation and Vulnerability" report (Pörtner et al., 2022). This definition encompasses various infrastructures as products of integration and co-design, supported by governance system that enhances community relationships and promotes economic growth, health, and quality of life.

According to the definition provided by the IPCC, however, there is a type of infrastructure – the social one – which consists of social, cultural, and financial institutions and activities that support community well-being. This fourth infrastructure underpins the welfare state of national and local contexts and also includes the places and artifacts that host these functions.

The school is probably one of the most important social infrastructures – in reducing socio-spatial inequality (Mela & Toldo, 2019) –, as it fosters the thinking of the communities of the coming years.

Really, the significant urban function of the school as an interconnected social infrastructure has been highlighted in numerous studies across different fields, such as urban economics, educational sciences, and urban planning. For example, it can be recognized that where the urban fabric is more tenuous and the density of urban opportunities is lower, educational outcomes are of lower quality (Gibbons & Silva, 2008), and this often leads to a vicious cycle that progressively worsens the initial condition.

However, where the school becomes a cooperative social infrastructure, it is possible to achieve overall improvement outcomes (Ralls,2019), also concerning the redesign of shared space between school and city (Miles et al.,2023).

The role of educational processes that enable the creation of new connections within the social infrastructure system appears significant. Carta (1999) discusses the importance of territorial and urban cultural heritage as a key element in identity building, citing, among other things, the social and identity functions of cultural heritage as defined by UNESCO (1972) and later reiterated by Fabrizio (1995). The key challenge is to integrate educational objectives into a coherent local strategy and to promote cross-sectoral integration, acting simultaneously on both fronts: that of social inclusion and the fight against inequalities and poverty (Colantonio, 2011). Integrated urban strategies should include interrelated actions to improve the economic, environmental, climatic, and social conditions of urban areas.

For this reason, educational action with younger generations is a significant part of constructing social infrastructure, its spatialization, and the ability of communities to produce systemic projects that harmoniously involve the infrastructures as defined by Pörtner et al. (2022).

Experts in urban and regional planning play a relevant role in tackling both education and urban regeneration challenges in order to improve social infrastructures, and a frequent point of contact between education and the challenge of urban regeneration is found in the so-called 'argumentative turn' in planning (Fischer & Forester, 1993).

Really, community engagement and support, participative approaches and co-design activities are a relevant part of the "communicative turn" in urban planning. The still-ongoing shift of planning practice toward a more cooperative and participatory process of urban production (Forester, 1999; Healey, 1997) spurs the development of numerous methods and techniques for participation in planning processes. Planning theorists described this progressive change as the "communicative turn" (Healey, 1996), closely related to the "argumentative turn".

Based on this view, urban planning is increasingly seen as a communication process that balances the interests and needs of different stakeholders in the city. This approach promotes integrative actions across social, economic, and spatial domains, as noted by Carta (2017). Urban development faces challenges such as globalization, demographic changes, and financial constraints, often overwhelming municipalities' creative and economic capacities. Therefore, cooperation among various actor groups and an interdisciplinary approach is essential. Sustainable urban planners must address these demands to ensure spatial compatibility and viability.

Education has emerged as a key factor in urban development, especially in areas highlighted by Save the Children (2022), where opportunities are limited, and schools serve as critical cultural and legal anchors. In these contexts, discussions around education and training infrastructure are vital for fostering integration and societal participation. Initiatives aimed at improving educational access in marginalized neighborhoods are crucial for addressing socio-spatial disparities and mitigating polarization exacerbated by economic crises.

Knowledge and skills acquisition, as well as lifelong learning, raise questions about a suitable neighbourhood context and how places of learning are designed. In Southern Europe, where traditional educational models may not adequately address diverse populations' needs, innovative approaches to educational infrastructure are essential. This includes creating flexible learning environments that accommodate both formal and informal education, fostering community engagement and support (UNESCO, 2015).

Furthermore, the design of educational infrastructure and the social urban development of deprived neighbourhood programs must be context sensitive. Programs should reflect the cultural and social dynamics of the neighbourhoods they serve, ensuring that they are not only accessible but also relevant to the local population. These programs are created in tandem with urban planners and designers and implemented in communities to ease educational inequality.

In cities like Barcelona and Lisbon, collaborative efforts between local governments, educational institutions, and community organizations have shown promise in developing integrated approaches to urban regeneration that prioritize educational equity. Such initiatives can lead to sustainable urban development that empowers residents and enhances overall quality of life.

Subsequently, starting from the argumentative turn in planning and the integrated vision of socio-spatial infrastructure, the article makes a common thread that connects these themes, using an operational method to leverage the educational context in order to enhance awareness of what quality of life means for citizens — starting with the youngest students in primary and secondary schools — as a key component of socio-spatial equity, which is a fundamental part of the project for a new creative and non-destructive Anthropocene.

This article, at a glance, presents the method, application, and results of a field research activity developed within the framework of the project P.arch. Playground per architetti di comunità.

The results stem from a customized co-design process for open spaces in schools involved in the project in Favara (Agrigento, Sicily) and Rome (Primavalle). A school in Palermo (San Giovanni Apostolo) adopted a similar methodology but with unique adaptations not covered here. The following paragraphs detail the objectives and modular organization of the P.arch Project, focusing on the Creative Architecture 2 Module led by the UniPA research group. The methodology, actions, and results are outlined through three phases of the workshop conducted in Rome and Favara. Ultimately, applying social innovation with youth enhances systemic efforts to address the Anthropocene crisis.

2. Materials and method

2.1 The P.arch project

The activities – whose results are reported here – were carried out by the research group from the Department of Architecture[1] as part of the project "P.arch. Playground per architetti di comunità", a project selected by "Con i Bambini" Social Enterprise under the Fund for the Fight Against Child Educational Poverty (project lead: Farm Cultural Park, Favara, Italy).

[1] The research group from the DARCH at UniPA was led by Prof. Maurizio Carta, Scientific Coordinator for DARCH and contact person for the Scientific Committee for the project. The authors of this article, Prof. Daniele Ronsivalle and Prof. Annalisa Contato, each had specific roles within the project: Prof. Ronsivalle served as the Governance Contact for the project (regarding the I.C. Falcone Borsellino School in Favara and I.C. Via Maffi in Rome), while Prof. Contato was responsible for the Creative Architecture Workshops (also concerning the I.C. Falcone Borsellino School in Favara and I.C. Via Maffi in Rome).

Starting from Save the Children's definition of educational poverty (2014), the project aimed to address this issue through policies, projects, and experiments designed to develop educational wealth, strengthen the educating community, and transform the city itself into an educational city capable of offering its inhabitants growth opportunities.

The experiment involved the regions of Sicily and Lazio[2] to ensure a widespread impact of the project, suitable for a comparative and evaluative analysis that ensures coverage in Southern and Central Italy. The choice of territories was also guided by the involvement of schools located in marginalized areas, not only in their geographical location (such as metropolitan peripheries or hard-to-reach places like Favara, a town in the Sicilian hinterland) but also in their socio-cultural dimension. These are fragile territories with high rates of educational poverty, school dropouts, social distress, and issues of multi-ethnic and multicultural integration. Thus, these territories lack personal, cultural, professional, and social growth opportunities for young people. In these "sample" contexts, educating children in new design practices thus becomes a resource for reimagining abandoned or underutilized spaces (due to neglect by the responsible public institution) within the school premises. By broadening the perspective to the neighbourhood's urban context, it also serves as a way to reimagine new urban spaces in the perspective of urban commons (Esopi, 2018) as collective resources that are enriched through individual interaction, increasing the value of the urban system, improving quality of life, and fostering cooperation, social capital, creativity, and encouraging the community in participation and co-design processes (Scheiber & Mifsud, 2024).

The P.arch project thus experimented with an innovative and replicable educational process, based on creative methodologies and active relationships, structured into four parallel modules: 1) "Creative Architecture 1", in this module children studied their local areas and developed regenerative projects based on their needs, as well as principles of environmental sustainability and integration (D'Amico, 2024); 2) "Creative Architecture 2", in which children designed both the internal and external spaces of schools and solutions to regenerate neighbourhoods, producing projects to build pieces of Augmented City (Carta, 2017; 2021) where space sharing and collective interest are predominant; 3) "Territorial Storytelling", within which children created tourist itineraries that combined the history of local heritage with their personal stories and organized guided tours conducted by themselves; 4) "Urban Gaming", using Minecraft children redesigned unused/underutilized areas.

The research group from the Department of Architecture was responsible for the "Creative Architecture 2" module, experimenting with the concept of "educational wealth" through the guiding principle that the city is the primary "entity" (and not just a place) that contributes to enriching its inhabitants.

A "rich educational city" offers its inhabitants a full range of growth opportunities, and the city, with its spatial and social organization, is an integral part of the "educating community". Spaces and architecture play a profound educational role, and when this role is enhanced by citizen participation, they can create conditions for cultural growth.

2.2 The "Creative Architecture 2" Module

The Creative Architecture 2 Module of the P.arch project focused on the tangible realization of the "rich educational city", helping students to think about the spaces in their neighbourhood as starting points for rediscovering their identity, sense of community, and fostering responsibility towards public spaces for collective use (Carta, 2022). It also integrated the school into the concept of a "place open to the community", where different generations can meet and grow together, furthering the idea of an educational community.

[2] The schools involved in the project were: Comprehensive Institute (C.I.) "Falcone Borsellino" in the municipality of Favara (AG); C.I. "Giuliana Saladino" in the municipality of Palermo; and C.I. "Via Maffi" in the municipality of Rome.

To achieve the project's goals, Module 2 proposed a list of elements capable of enriching the city to help the community overcome educational poverty conditions and strengthen social fabric and personal identity, including:

- Greater synergy between conceived, perceived, and experienced spaces through new modelling of the "right to the city";
- More spaces for local storytelling, following the model of community spaces or interpretation centres;
- More libraries accessible to children, serving as squares of knowledge and relational space, public cognitive-relational spaces;
- More open spaces for play, providing opportunities for emotional interaction with urban space (utilizing opportunities offered by urban gaming);
- More positive urban landmarks that can serve as tools for inspiration and urban identity building;
- Increased direct experience in the performing arts (both as participants and spectators), enhancing the emotional dimension of the city;
- Reduced commercial desertification and spatial-functional homogenization, with a return to urban multifunctionality, countering both gentrification and hipsterfication;
- More fluid and permeable spaces to accommodate and nurture the multiple communities living in increasingly cosmopolitan cities, able to harness local opportunities and global vitality.

All these elements were central to the educational experimentation of the Module and served as guiding principles throughout the four years of field application (Fig.2).

In the first year of activities, "play" was used as a tool to guide children in understanding their neighbourhood spaces, identifying solutions for transforming and regenerating the urban context in which they live to build parts of city where space sharing and collective interest would be predominant. To achieve this, the Module used the paradigm of the Augmented City that "perceives the demands of a society more networked and knowledge-based, that answers to the global change and new circular metabolism. […] Augmented City acts simultaneously on cultural, social, environmental and economics components to activate a human/urban regeneration" (Carta, 2017:7).

They also learned to identify quality, well-being, inclusion, and creativity objectives derived from the Augmented City Circle (Carta, 2017), which were translated into design devices they created, applying the process of the Cityforming Protocol (Carta, 2015). This Protocol is a self-regenerating process able to reactivate by stages the stationary metabolism of an area, starting from its talent regenerative components, acting for incremental and adaptive steps required to produce partial results that become the foundation of the next generative phase. The application of this planning protocol allowed for identifying those places and actions that could serve as "creative colonies" (the first step of the Protocol) meaning initial sites from which the transformation process could start with minimal financial commitment and then evolve and expand in subsequent phases due to the effects produced by the initial interventions.

In the second year of the Module, the children developed a general program for the urban context (a sort of master plan) and engaged in co-design activities for both the interior and exterior spaces of the schools, where previously identified places for "colonization" were located. The design dimension thus ranged from the urban context scale (urban spaces and connections between spaces and functions) to the building scale (the school).

The third and fourth years of Module 2 saw the activation of co-design and subsequent co-realization of collective urban spaces within the interior and exterior of the schools, aiming to create stable Community Hubs - a school space capable of enabling a variety of relationships and offering opportunities, also in connection with the needs of the neighborhood's residents (Bianchi & Moscarelli, 2024) - , starting from tactical urbanism applications (Bazzu & Talu, 2016; Boglietti et al., 2024; Casanova & Hernandez, 2014; Lydon & Garcia, 2015).

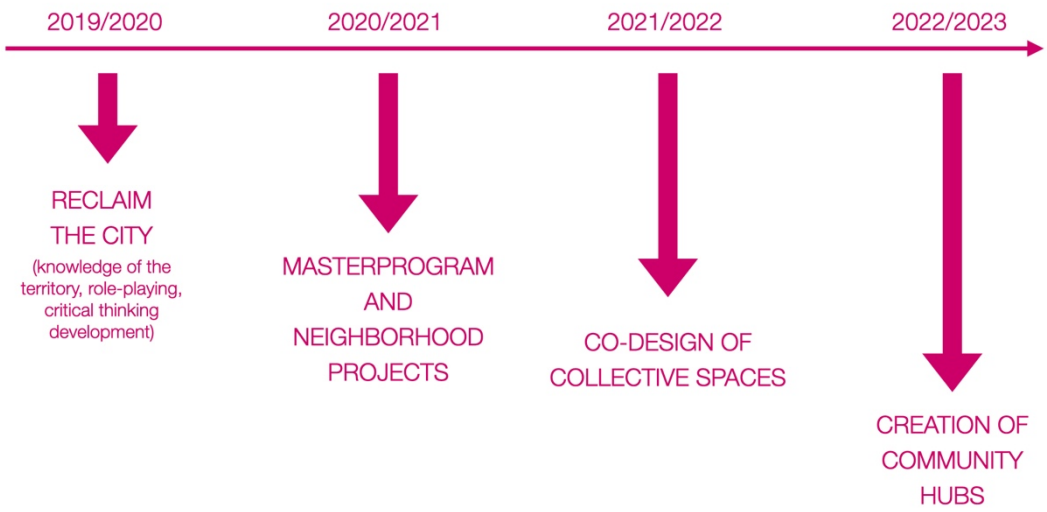

Fig.2 Objectives of the Creative Architecture Module 2 Across the Four School Years

3. Results produced in the individual work phases

3.1 The Game "Reclaim the City"

As Module 2 aimed to develop an innovative and replicable educational model based on creative and enjoyable methodologies to enhance both cognitive and non-cognitive soft skills in children, the proposed approach integrates two specific methodologies: project-based learning and authentic learning.

The adopted methodological approach aims to serve as a model through the use of fun and creative tools (game construction and gameplay), as well as more traditional tools such as reading, writing, and drawing. By applying these tools children are guided to understand the importance of interacting between different forms of creative expression and to recognize/discover their unique talents.

The methodology included theoretical and workshop sessions and direct involvement of the children in designing projects for transforming the places they regularly inhabit and/or traverse.

In the first year, children participated in a role-playing game, group work, urban context walks, and workshop activities to stimulate their expressiveness, and creativity, and enhance relational skills. They were encouraged to practice presenting their thoughts and the outcomes of the workshops, a moment of growth and self-awareness aimed at boosting self-esteem and enhancing soft skills.

In detail, the following teaching methodologies were adopted:

- Informal cooperative learning to proactively develop problem-solving skills and social abilities;
- Problem solving for the development of common knowledge and design objectives, to be applied in the development of the game "Reclaim the City";
- Simulation for applying the game "Reclaim the City" and evaluating the project outcomes;
- Problem-based learning during the phase of assessing transformation objectives, simulation, and project realization.

The teaching methodology of the game was chosen to stimulate the children's creativity and develop relational processes with their peers. The game method, which was designed and implemented with students, serves as a moment of sharing and creativity. It allowed them to design the urban context of their lives and, above all, to view transformation as a "reclamation" of spaces and identities.

The game is based on an approach where the places to be "reclaimed" are the endogenous components of the urban context (strengths and weaknesses), and the means (or weapons) of reclamation are represented

by the design tools that can be used. The purpose of the game was to produce a map of future transformations for the urban context where the school is located and where the students live.

All components of the game (board, playing cards, and rules) were created by the children themselves, with guidance from the UniPa research group.

During the Module, the students carried out the following activities (Fig.3): identifying the endogenous components of the area through a "neighbourhood walk" and on-site discussion; reading and understanding the neighbourhood map and recognizing the places/endogenous components; creating the game base (board) by drawing the map of the urban context on which all possible places of interest to reclaim/transform were marked; creating objective cards, which contained the definition of the desired functions through writing and drawing; creating "weapon" cards, made both by writing and drawing to define the design tools needed to achieve the goals; creating character sheets, aimed at understanding the importance of stakeholders' roles and identifying the "mayor" with veto power over the project; writing the game rules; conducting the game: creating a draft map of the transformation colonies of the urban context around the school; presenting the results and new narration.

The Module allowed students to develop and strengthen their cognitive and non-cognitive skills, particularly technical skills in drafting projects for creating Augmented Cities. The activities provided the opportunity for children to develop critical thinking about the places where they live and/or spend their daily lives, enhancing their sense of community and the importance of participation in growth processes, both personal and in terms of the community sense they are aiming for (Francis et al., 2012).

Fig.3 The Phases of the Game "Reclaim the City"

3.2 Playing with Bricks to build future scenarios

The objectives of the second year were to develop critical and complex thinking through the technique of guided discussion, leading students to reflect on the outcomes of the role-playing game conducted during the first workshop and they were encouraged to evaluate whether the identified design solutions needed to be integrated and/or modified. The concepts of space sharing and collective interest were established as the foundation for enhancing the overall vision of the quality of the entire urban context.

However, the second year was characterized by the restrictions due to the Covid-19 pandemic, which required students to work individually. Therefore, the Module activities had to revise the teaching, both to prevent

individual difficulties from negatively impacting the educational richness objectives and to still construct a unified overall project in which all students, individually, participated by contributing in synergy with the class group.

For these reasons, it was decided to experiment with the use of bricks for both constructing the model of the reference urban context and for designing urban regeneration projects in urban contexts identified by the students as potential "colonies" of the urban regeneration process.

Through playing with the bricks, creativity (Schulz et al., 2015) and the pleasure of working together were stimulated, even though the students worked individually on the operational tasks. This contributed to the creation of a model of the entire city, which was useful for improving the understanding of spatiality at the urban scale (already initiated during the first year's activities) and for stimulating further reflections on the necessary transformations (Fig.4).

The use of this tool ensured that each student could work individually and safely, and the ease of using the bricks, which do not require specific technical skills (unlike, for example, manual drawing activities that could challenge students who do not yet have good drawing abilities), allowed all students to develop their creativity with simplicity. Additionally, the students' autonomy, the value of group work and community strength were emphasized by organizing the activities so that each student built a piece of a whole.

The children's creativity was stimulated through various constructions with the bricks, which also allowed for an assessment of their abstraction and vision skills. Initially, each child was given a base plate corresponding to a portion of the base map to "reconfigure" and a set of bricks. This way, even though each child worked individually, they all collectively contributed to the creation of the model of the reference urban context. This model served as the basis for subsequent reflections on which areas and/or buildings to intervene in to implement actions of urban regeneration.

The students all alternately experimented with the design of open spaces and enclosed areas. The creation of urban projects saw an increase in the students' creative and collaborative phases, expressed through spontaneous coordination for the development of complementary projects located in specific areas of the city.

The use of this method/game, although initially designed to address issues related to the health emergency, proved to be highly effective. Not only was it easily replicable and adaptable to various educational experimentation needs, but it also strongly stimulated both individual creativity and the ability to work complementarily with the entire class. This approach activated both cognitive and non-cognitive skills.

Fig.4 The methodological and operational steps for the implementation of the Masterprogram and neighbourhood projects

3.3 Co-design of collective spaces and the creation of Community Hubs

The last two school years focused on the co-design and co-creation of communal spaces, with the aim of establishing a Community Hub as a stable presence for the community. In this project, co-design was understood as an approach aimed at broad and complex transformation processes, integrating the concept of social innovation and evolving towards the idea of an open process where a multitude of small, participatory initiatives interact to achieve a broader vision (Manzini & Rizzo, 2011).

Fig.5 The operational phases of the co-design of collective spaces

The co-design process implemented was understood as a participatory process throughout all its phases, from ideation to realization (Sanders & Stappers, 2008), following key principles such as: "active participation", where all involved parties are invited to contribute ideas, knowledge, and experiences; "collaboration", where teamwork is essential for achieving shared and integrated solutions; "inclusivity", promoting broad participation to represent diverse perspectives and needs; "transparency", as the process is open and clear to all participants; and "innovation", as the combination of various skills and viewpoints stimulates creativity and innovation.

The activities carried out primarily focused on several key points:

- Imagination: stimulating imagination through representation and creation of drawings, writings on various themes, with the goal of activating free and as unstructured as possible creative processes;
- Body and Space: getting acquainted with one's own body, the body in space, both individually and collectively, through exercises exploring the external spaces of the school complex;
- Material: getting acquainted with construction materials, their texture, and the possibilities of transformation, assembly, and finishing. Creating small artifacts/prototypes from loose pieces of wood and other materials like cardboard;
- Design by Doing: project and experimentation trials starting from drawing exercises and the words collected around the proposed theme. The space is engaged through the collective creation of project prototypes intended for realization;
- Construction: building habitable devices starting from prototypes assembled during the experimentation process. During the construction phase, the children become familiar with tools and construction techniques, managing all phases of the process independently with the support of the Unipa research group.

The two years of this phase allowed for the completion and implementation of what was achieved in the first year of co-design, increasing the difficulty level of the product due to the students' now attained awareness of the different phases of the process and the cognitive and non-cognitive skills they had developed.

The ability to work in groups, coordinate, and complement each other through all phases was widely achieved. Additionally, there was an increase in creativity, accompanied by greater awareness of one's abilities and the concepts of urban regeneration and the importance of public space.

All the students chose to work on creating a communal space within the only green area present in the school complex, recognizing it as a refuge from overly built areas and as a contributor to individual and collective well-being, more attractive and pleasant to live in than other locations.

4. Conclusion

Research has shown that activities conducted in socioeconomically diverse contexts with young people for the innovative development of grassroots co-design processes can be crucial in producing a new model of community development.

The absence of public institutions responsible for the spaces subsequently transformed by the tactical actions of the P.arch project led to the starting condition and the project's demand for the development of this new experimental model of community development.

Previous situations of inefficiency and functional poverty in some areas highlighted the need to activate collective resources in Favara and Rome-Primavalle to fill the gap left by the public sector, through actions in urban commons aimed at enriching individual interaction, improving quality of life, and fostering cooperation and creativity. The P.arch initiative has enabled the start of a process to consistently meet the needs of the community and individual citizens. Numerous examples, even at very different urban scales, reveal the need to initiate such processes to rebalance – through the strength of communities – the functional deficits of our cities (Esopi, 2018).

The development and outcomes of the project have demonstrated that the educational action with the young generations of Favara and Rome-Primavalle has played a significant role in building community awareness. This can lead to the strengthening of the social infrastructure, its spatialization, and the capacity of communities to produce systemic projects that harmoniously involve the four infrastructures defined by Pörtner et al. (2022) for regenerating the urban environment.

Social innovation can ensure the transition to regenerative city models where the engine for a new development paradigm lies in the young generations. When trained in socio-spatial relationships as well as in basic cognitive skills, they can develop an evolutionary mechanism for urban development aimed at promoting actions that provide environmental, social, and economic well-being, leading towards a new integral ecology (Francesco, 2020).

However, the challenges to be addressed and resolved in social innovation processes such as those implemented by the P.arch project and the Creative Architecture Module 2 are still significant for disciplinary advancement. A new settlement strategy is indeed necessary to ensure that these experimental processes can guarantee stable innovation. This strategy must take into account numerous aspects. First and foremost, the integration of co-design within governance processes is essential. This includes regulatory planning and land-use designation, the formulation of general urban regeneration strategies, and the social and economic management of neighbourhood realities. Indeed, there are examples of tactical urbanism or unconventional bottom-up actions (such as guerrilla urbanism, guerrilla gardening, etc.) that, after an initial phase of enthusiasm, have left behind debris, with no continuity of intervention or stable development (Bazzu & Talu, 2016; Casanova & Hernandez, 2014; Lydon & Garcia, 2015). The second aspect concerns the actual ability of these interventions to stimulate widespread transformation. In other words, can a prototype of transformation be capable of altering large spatial contexts, often suffering from social poverty conditions as discussed in the earlier sections of this article? Certainly, the commitment of the local administration is crucial to ensure the dissemination and socio-spatial embedding of the approach introduced by the project within the relevant urban context. The third aspect concerns, as a final consequence, the economic sustainability of such interventions. Interventions funded by public bodies, NGOs, cultural foundations, and social enterprises are financially sustainable as long as the funding flow can support the process; however, the sustainability of socio-spatial transformation may falter, leading to physical neglect and social disheartenment due to the sense of abandonment. To ensure that the process can be elevated to a different, more stable, and replicable level with upscaling, it is necessary to adopt incremental and adaptive urban regeneration processes, such as the Cityforming Protocol (Carta, 2015), to provide a concrete possibility for the medium-term development of tactical and grassroots transformation projects that have evolved over these years.

Author Contributions

This contribution is the result of the research activities of the P.arch project. Both authors contributed to the formulation and conceptualisation of the survey problem and the construction of the empirical basis of the article. However, the drafting of paragraphs 1.2; 2.1; 3.2 and 4 are to be attributed to Daniele Ronsivalle; the drafting of the paragraphs 1.1; 2.2; 3.1; 3.3 and 4 are to be attributed to Annalisa Contato.

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Image Sources

Fig.1: Elaboration by the authors;

Fig.2: Elaboration by the authors;

Fig.3: Elaboration by the authors;

Fig.4: Elaboration by the authors;

Fig.5: Elaboration by the authors.

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PED's paradigm shift as regenerative city models between innovation, green infrastructures and urban form

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Abstract
In 2007, the European Union launched The Strategic Energy Technology Plan (SET), which is in fact the framework within which some ecological transition policies for the European territory are inserted. Contributing to the ambitious objectives of the European Strategic Energy Technology (SET) Plan, the programme "Positive Energy Neighbourhoods and Neighbourhoods for Sustainable Urban Development" supports the planning, deployment and deployment of 100 Positive Energy Districts by 2025.
Even the new Horizon Europe research and innovation plan (which will cover the period 2021-2027), Europe aims to tackle some global challenges affecting our cities and our society with determination: health and safety, digitalisation, energy and climate change in the first place. The Positive Energy Districts are part of this perspective. It is supported by 20 EU Member States and conducted by JPI Urban Europe. The programme involves stakeholders from R&I funding networks, cities, industry, research organisations and citizens' organisations.
In this sense, wanting to focus the interest of this research – of which an extract can be found in these writings – we find a first decisive orientation – at the European level – through the declination of European policies. The paper, starting from the various international strategies promoted by intergovernmental subjects, focuses its attention on the very recent energy transition initiatives in the urban area. By examining some selected case studies, he defines a methodological approach - focused on case studies/good practices - that goes beyond the classic analytical approach by moving towards a more systemic design.

Keywords
PED; Urban regeneration; Green infrastructure

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1. Introduction

Recently, as we well know, environmental policies have been consolidated all over the planet especially with a focus on climate change. Both the UN and the EU have launched initiatives to relaunch best practices after the Paris Agreement in terms of Net Zero with SDG's.

This journey of sustainability -as even Peter Newman wrote (Newman, 2018)- builds on a series of historic global agreements: from the Bruntland Report to the Rio Conference, passing through the Aalborg Charters, the Mayors' Pacts on Energy Sustainability, the SDG 2030 and then to COP 21 which was where 196 countries signed up to Net Zero and the SDG's.

These have been based on UN processes and now nations and regions are establishing strategies for how to do this such as the recent *European Green Deal*. In this long journey, our communities have also increasingly understood the need for the ecological transition of settlements.

However all polytechnic class: urban planners, engineers, architects, and designers are not, yet, sure what it means for them and how we can make such cities of the future. The *Net Zero* with SDG's agenda is now quite clearly what we as urban professionals need to be applying to our cities and does build on decades of global and local work. But it's not at all clear how we should be making such a future unfold in cities of the future.

As Peter Newman argues (Newman, 2021) the last *Mitigation Report* (https://www.ipcc.ch/report/ar6/wg3/), and from researching actual projects that are trying to demonstrate Net Zero Cities with SDG's, are:

- The core technologies will be solar and wind, batteries and electric vehicles of all shapes and sizes as they are now cheaper and more effective than any other power and transport system in history;
- This has been recognised by the world of finance as well as most global governments and professional bodies but there remains a lot of momentum in the old fossil fuel-based systems that have built our cities and economies;
- Smart technology systems are the key to integrating these core technologies into buildings, precincts, corridors and different urban fabrics, to enable microgrids and local management systems that create net zero results and other SDG's;
- Local areas with their communities and varied economic activities, will thus be drawn into greater responsibility for how the Net Zero and SDG's agenda, are envisioned, procured and implemented;
- Historic urbanism with its emphasis on local place and walkability will be more important in the next economy than the large-scale modernist solutions we have used as the basis of power and transport based on fossil fuels.

In the end it should be added that a crucial role will also be played by green infrastructure and technologies for climate adaptation and mitigation in urban design and construction indeed as stated the IPCC (https://www.ipcc.ch/): "*The strategically planned interconnected set of natural and constructed ecological systems, green spaces and other landscape features that can provide functions and services including air and water purification, temperature management, floodwater management and coastal defence often with co-benefits for human and ecological well-being. Green infrastructure includes planted remnant native vegetation, soils, wetlands, parks and green open spaces, as well as building and street-level design interventions that incorporate vegetation"* (after Culwick & Bobbins, 2016). As we wrote in the abstract this contribution aims to provide to define methodological approach - focused on case studies/good practices - that goes beyond the classic analytical approach by moving towards a more systemic design on the basis of a greater understanding of the city and the territory and on the experimentation of technologies useful for achieving the ecological transition and a new model of urban regeneration. In the following paragraphs, some decisive contributions will be addressed, namely: in section 2 how to PED'S becomes a paradigm shift, as regenerative city models; In section 3 what are the characteristics to define and implement a positive energy district; section 4. New approach by the city's future; section 5 Climate change and its consequences in the urban design: adaptive-climatic measures and mitigative-climatic measures; conclusions.

2. PED'S paradigm shift: as regenerative city models

The theme of ecological transition is the new paradigmatic element of the progress of our species (Butera, 2023) and substantially permeates the different urban and territorial policies to the various dimensions of the city and the territory, increasingly penetrating the different paradigms of planning. The challenge posed by sustainability to co-living on earth seems to require a convergence of a plurality of institutional, scientific, technical, cultural and above all political subjects institutional, scientific, technical, cultural and above all urban and territorial policies to which reference will have to be made for the government of the territory (Palermo, 2021; Sgambati, 2022). In this sense, intergovernmental institutional actors at various scales and functions – such as the UN (with the 2030 Agenda and the IPCC Report 2022) and the EU – are actively engaged in assessing, monitoring and achieving full climate neutrality by 2050. The very recent New Green Deal and the most recent experiments, in the field of urban design, define some actions and more specifically: the Driving Urban Transition (DUT), the Positive Energy Districts (PED), the circular economy or the Circular Urban Economies Transition Pathway (CUE) in addition to the recent regulatory introductions of the various EU member states, including Italy, on Renewable Energy Communities (RECs). On these issues and actions, there is evidence that work is being done, mainly outside Italy, towards urban self-sustainability and this is evidenced by the various design case studies. All this defines differential urban development scenarios. As we said before with the new Horizon Europe research and innovation plan (which will cover the period 2021-2027), Europe aims to tackle some global challenges affecting our cities and our society with determination: health and safety, digitalisation, energy and climate change in the first place. The Positive Energy Districts are part of this perspective. Why and what are the key factors of a PED? And why are gaining a lot of importance in urban planning processes?

A. Energy districts and energy-positive neighbourhoods are an integral part of a comprehensive approach towards sustainable urbanisation and energy transition and involve several legal, regulatory, spatial, technological, social and economic aspects.
B. A Positive Energy District is seen as an urban district that is self-sufficient from an energy point of view and with zero CO2 emissions. Indeed, positive energy means that energy districts also play an important role in producing excess energy using renewable energy sources and feeding it back into the grid.
C. An energy-positive urban energy district combines the built environment, mobility, sustainable production and consumption to increase energy efficiency and reduce greenhouse gas emissions and to create added value for citizens. Positive Energy Districts also require integration between buildings, users and the energy network, mobility and IT systems.

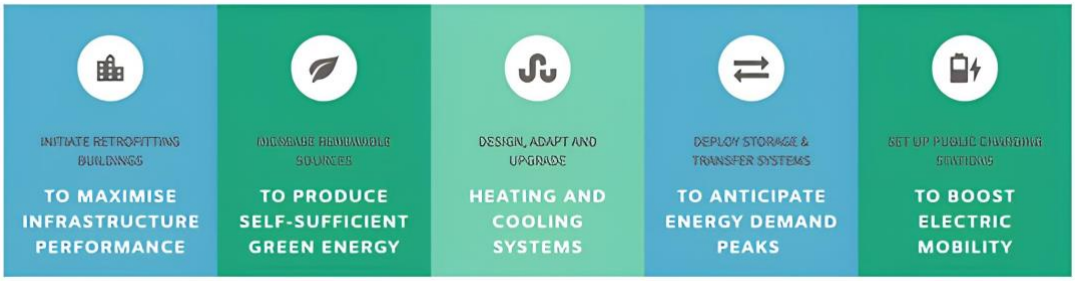

Fig.1 Balance diagram between energy efficiency, energy flexibility and local energy production

3. Characteristics of the Positive Energy Districts (PED)

We all understood clearly by now that both urban (Foster, 2024) and country living as Koolhaas (2020) would say, fully invests the individual, the community, society, and in turn space and territory, directing the dynamics of man's presence in the environment, geography (Martinotti, 2017; De Rossi, 2018) and politics and thus marking everyone's behaviors, actions, habits. Recently the European Union launched the Green Deal focusing

on: 1) Transforming our economy and societies; 2) Making transport sustainable for all; 3) Leading the third industrial revolution; 4) Cleaning our energy system; 5) Renovating buildings for greener lifestyles; 6) Working with nature to protect our planet and health; 7) Boosting global climate action. How we know the European context on green actions moves at different speeds and with different geographical repercussions, on the one hand the virtuosity of Northern Europe with examples of urban self-sustainability now almost fully operational and on the other hand in Southern Europe a situation that is still struggling to understand well and align with the major policies. It should be noted that in a first summary "perimeter" those actions that have received the most attention emerge and are the PEDs present in Europe - 61 in all - well documented by Urban Europe in the report "Europe towards Positive Energy Districts ", which is in fact the official source of European programs. In this sense, it is necessary to point out that although there are other similar initiatives, the reference goes to those institutionally recognized. It is necessary to define in advance some basic conditions for the realization of PED and as well as an approach holistic system that considers the complex system. Preliminary a Positive Energy District is influenced by some factors to consider:

PED Factors	Theme
The boundaries of the district	- Physical limits and boundaries of the urban environment, of the city, of the territory; - Rivers, lakes, hills, railway areas, city blocks, roads (motorways, local roads, etc.)
The geographical and urban morphology of the district (the shape of the settlements)	- The spatial location of neighborhoods, i.e. central, semi-peripheral, in rural and urban areas, or former industrial, commercial areas, in coastal areas. - Public transport (train, bus, tram, metro.); public urban spaces (e.g. squares, green areas, play areas). - Water supplies, network systems, existence of energy supplies. - Etc…
The location of the neighborhood	e.g. neighborhoods of public housing, or historic, or recently built residential mixed-commercial, etc.
The building characteristics of the neighborhood	We refer to the type of building-construction technology e.g.: masonry, concrete, steel, prefabricated, etc...
The characteristics and behavior of the occupants	- Sociographic ethnic groups e.g. Muslim, Christian, Jewish neighborhoods; - Types of prevalent use i.e. retail, artisanal, industrial; - The current use of energy resources, e.g. if water from own sources is used, or solar energy from existing technologies on individual units; - Type of workers (occupation class), self-producers, income levels, type of social conduct.

Tab.1 Ped factors

These mentioned above are just some of the factors that will have to be considered in the design and implementation of a PED. Subsequently, the PED cases selected technology building in according to the climate mitigation/adaptive measures and sub-actions adopted, distinguished by climate themes (energy transition, bioclimatic response, etc.), were characterized, of which a summary graph is shown in follow figure.
They can be distinguished in the four selected cases of PED, cases considered significant from the point of view of the green technologies proposed and the degree of planning and implementation achieved. Following an analysis of the PED realities present in Europe - 61 in all - well documented by Urban Europe in the report

"Europe towards Positive Energy Districts" (JPI Urban Europe, 2020) and by Fabrizio Tucci in the book "Towards climate neutrality of green architectures and cities" (Tucci, 2021), four PED cases were selected that were considered significant from the point of view of the green technologies proposed and the degree of implementation achieved, or whether they have been implemented or in any case are being implemented, in this case four case studies, just for example, were selected:

- La Fleuriaye (FR);
- Hammarby Sjöstad (SE);
- Ready Vaxjo (SE);
- Murs de Monseigneur, La Cerisaie (FR).

These previously mentioned are the cases that are considered more mature and that have been observed with greater attention even by specialist scholars (Tucci, 2023).

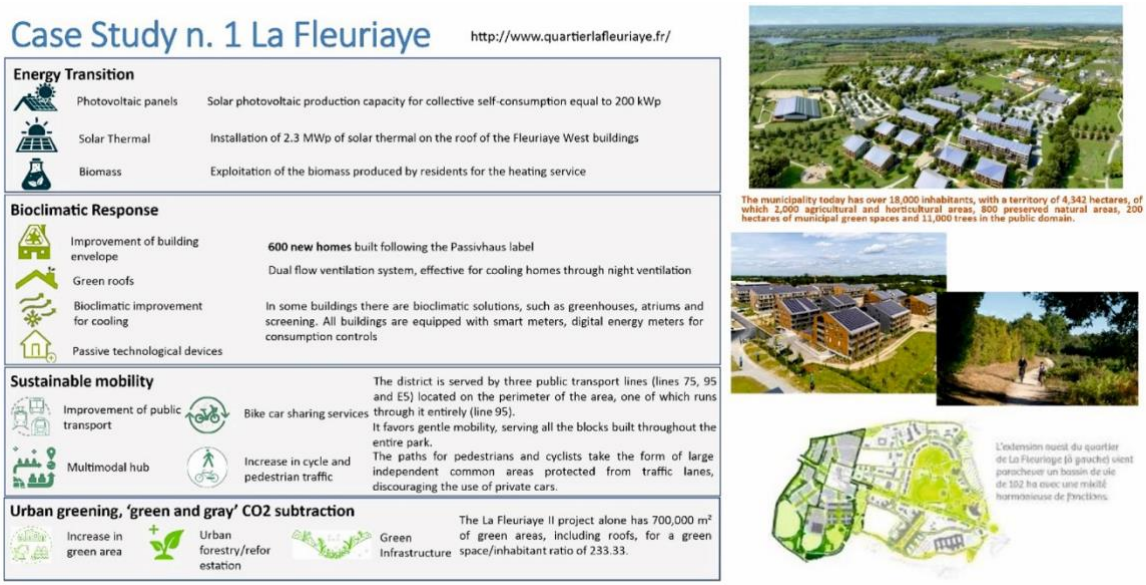

Fig.2 Case Study_La Fleuriaye (France)

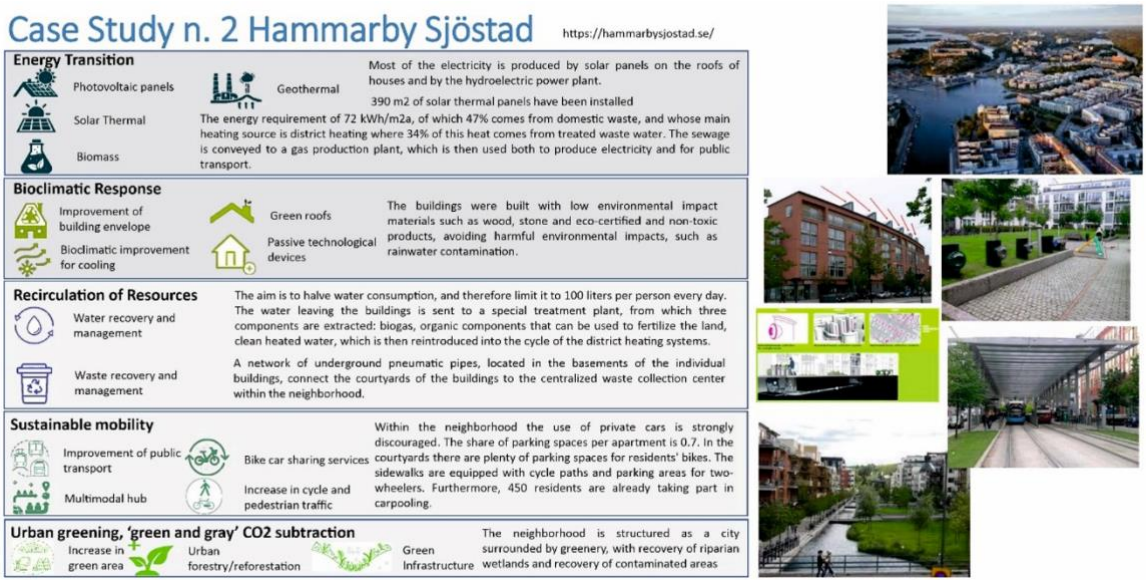

Fig.3 Case Study_Hammarby Sjöstad (Sweden)

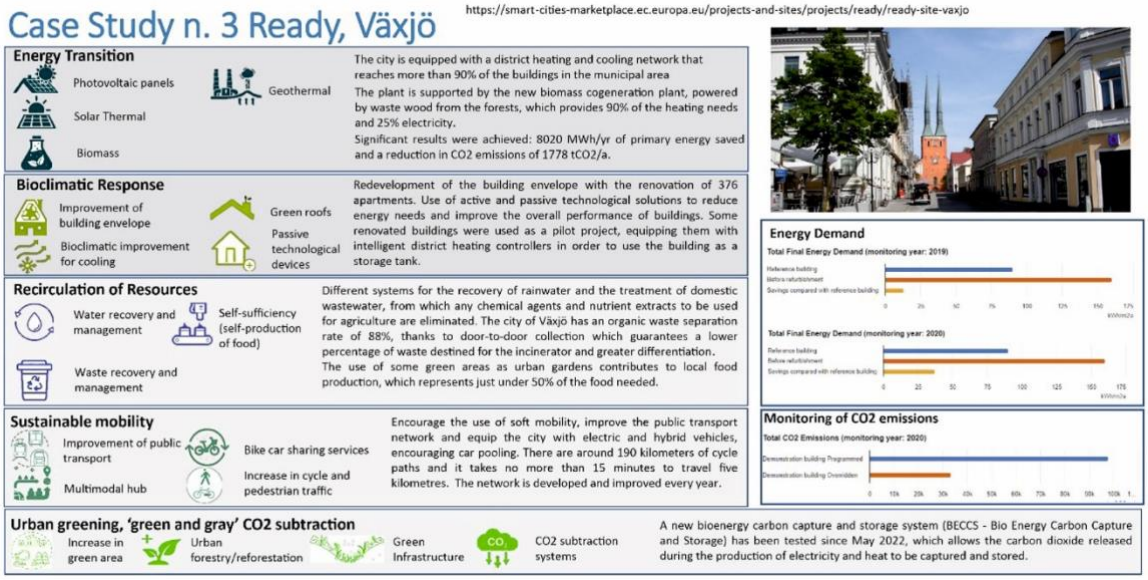

Fig.4 Case Study_Ready, Växjö (Sweden)

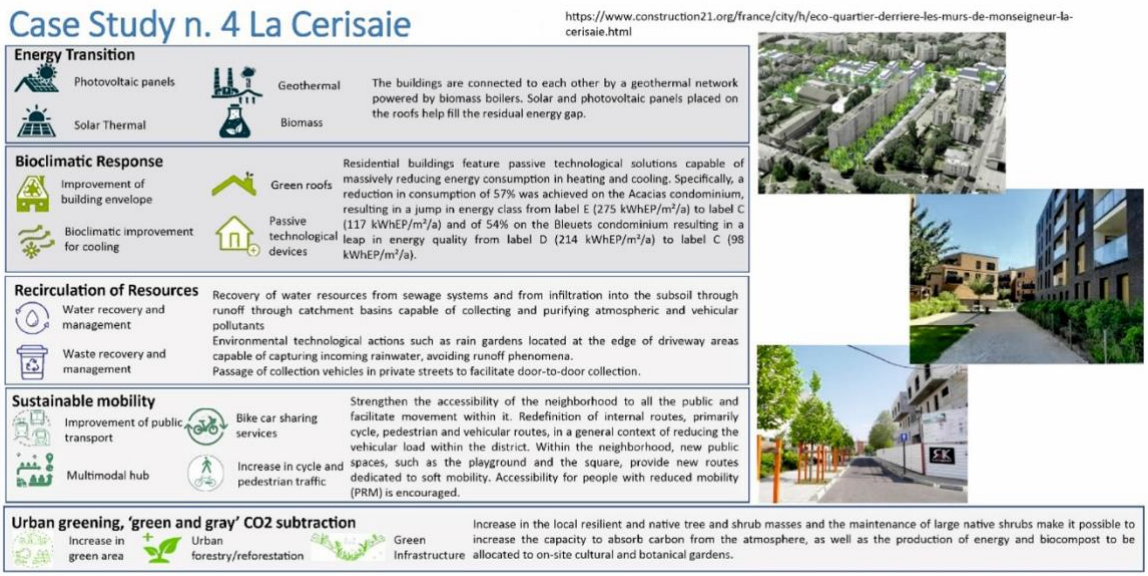

Fig.5 Case Study_La Cerisaie, (France)

4. New approach by the cities future

Positive energy districts change the way we interpret city design. Compared to the past, there is an urgent need to understand the epochal changes that the urban era has brought about. Sustainability at various scales, types and levels, is today a declared goal to be achieved for all of us for productive growth (social, cultural, economic, ...), but it is also, fundamentally, the achievement of a point of equilibrium of our planet, of the evolution of our species (Meadows et al., 1972). The complexity in which we live requires a lucid look at the (eco) systemic relationships of the planet (Bertalanffy, 1969; Butera, 2020; Lovelock, 1979; Odum, 1972; Tom, 1980), relationships that seem distant from us, but which, instead, involve us directly. This new and sought-after balance represents above all a new pact between man and the environment, a pact that is necessary to face the complexity in which we live, a complexity that requires a look at the systemic relationships and interconnections of the planet, relationships and interconnections that involve us intimately as has recently been demonstrated to us in the last five years. The effects of climate change, ongoing conflicts and the change in the geopolitical situation (Fabbri, 2023; Vince, 2021), the long wave of the covid-19 health

emergency (Capasso & Mazzeo, 2020), big data, artificial intelligence (AI), etc. do nothing but underline the ways in which we produce and consume, move and organize spaces, places and contexts, how we develop energy and distribute it, all these actions have significant impacts on our habitats of which we are increasingly aware. As both environmental scientists and various urban planners have been arguing for many years now (Crutzen and Stoermer, 2000; Newman, 2012; IPCC Report, 2022), the theme of ecological transition is the new paradigmatic element of the progress of our species and substantially permeates the different urban and territorial policies to the various dimensions of the city and the territory, penetrating more and more into the different models of planning. It is clear to all of us that the ecological transition passes through the energy transition (and in this case decarbonization), the climate transition and also an economic transition (Stiglitz, 2010; Beck, 2017), in the wake of what has been said, it is possible to note that a large part of the planet's inhabitants are now aware of the need for policies to reduce the climate crisis (Newman, 2019; Butera, 2023; Pileri, 2021), the preservation of natural resources, the need and the tendency, as observed by the IEA, towards energy efficiency of progressive interest and use. Just as intergovernmental institutional actors at various scales and functions – such as the UN (with the IPCC Report 2022) and the EU – are actively engaged in assessing, monitoring and achieving climate neutrality by 2050. An extremely ambitious goal because it implies the ability to make countries, industries, transport, construction, mobility, productivity, agriculture... with zero emissions. Certainly, the ecological transition necessarily implies that – to be achieved – there must be a radical transformation of the economic and cultural model that has permeated the development of humanity over the last two hundred years (Butera, 2023), a different vision of the future (Sachs, 2022).

In the field of urban and territorial planning we are in an era of great change, the physical systems of modern urban planning that once concerned the architecture and classical engineering of the city (Sitte, 1889), its composition and the projection of ambitions on it (Le Corbusier, 1937) of the landscape (Cullen, 1961) and, subsequently, due to the expansion of cities, also of the territory (Gregotti, 1968; Samonà, 1971; De Carlo, 1976) have changed radically, complicating themselves in several dimensions and extensions (Sassen, 2013) that are not always manageable by ordinary planning tools (Gregotti, 2014).

It follows that dealing with planning – even in operational tools – preliminarily implies a holistic approach, a much broader look (Indovina, 2014), a complex matrix reading that concerns the ecology of systems, the elements and their relationships (Morin, 2006; Chomsky, 2020) not always physical but increasingly spatial, fluctuating, interconnected even in immaterial dimensions that concerns the individual and his movement/interaction in the context (Moreno, 2023).

The time has come to start rethinking new models of cities, it is no longer possible to continue to adapt nineteenth-century planning models (through functional zoning) to cities that in the meantime have been radically transformed by addition and with new technologies.

5. Climate change and its consequences in the urban design: adaptive-climatic measures and mitigative-climatic measures

In the next three decades, nearly 80% of the population is expected to live in cities and that, on a global scale, the areas urban areas will see an increase in the population settled in cities up to almost 7 billion people, which will be more than two-thirds of the whole of humanity. And at the same time there is the awareness that the cities will be less and less livable, due to climate change, unstable weather conditions and weather events extreme (Tucci, 2023).

This has led, and is always continuing to bring more incisively, to widespread impacts on food and water security, on human health, the economy and society, with its losses and damage to nature and human settlements that have now for at least two decades we have learned to know in their progressive virulence.

THEME	TYPES OF INTERVENTIONS	TYPOLOGICAL DESCRIPTION	ADAPTIVE-CLIMATIC	MITIGATIVE – CLIMATIC
Energy Transition	Photovoltaic panels	Exploitation of solar energy through photovoltaic panels that convert it into electricity.	+	+ + + +
	Solar thermal system	It is a system which, by exploiting solar rays, transforms solar energy into thermal energy without producing harmful emissions	+	+ + + +
	Biomass thermal power plant (neighborhood level)	A biomass power plant is an electrical and/or thermal power plant which for its operation uses the energy obtainable from organic matter without transforming it through biochemical (fermentation, anaerobic digestion) or chemical processes.	+ +	+ + +
	Geothermal and district heating (at neighborhood level)	District heating is an innovative energy transport and distribution system that is used for heating, cooling and obtaining hot water. The founding element of district heating are cogeneration plants, where heat is produced which is then inserted into the distribution network, so as to reach individual homes. The peculiarity of these systems consists in remote operation and in the intrinsic possibility of exploiting a resource coming from the subsoil, namely geothermal energy.	+ +	+ + + +
Bioclimatic response	Improvement of the building envelope	A well-designed and constructed building envelope can significantly improve the energy efficiency of the building, reducing energy consumption for heating and cooling and therefore contributing to overall energy savings and environmental sustainability. This can be achieved in various ways, for example: providing adequate thermal insulation, minimizing thermal bridges, using adequate and certified materials, etc.	+ +	+ + +
	Green roofs	It is a type of roof that involves the planting of vegetation on the roof of a building, with the aim of improving its performance and helping to reduce its environmental impact.	+ +	+ + +
	Cooling improvement	Set of solutions that promote the cooling of the internal environments of buildings, such as solar shading, ventilation systems, etc.	+ + +	+ +
	Passive technological devices	The design of an architectural organism with passive criteria must live in close interrelation with the environment. In this sense, an analysis is carried out of all the possible relationships between the building and the environment, leading to the study of the construction details and the materials with which the building has been or will be built, taking into consideration the seasonality, the orientation of exposure to the sun, the surface of transparent glass, etc.	+ + +	+ +
Mixité Functional and proximity	15 minute city	The "15-Minutes Cities", i.e. cities that envisage the reorganization of the urban fabric in such a way that residents can carry out essential activities such as going to work, school, the doctor or shopping within 15 minutes on foot (or by bike) from your home.	+	+ +
	Typological mix for accommodation	The mixité is given by the set of strategic actions that concern the creation of relational and exchange networks, aimed at improving density, diversity, proximity and digitalisation, to reactivate the dynamics of urban areas and invite citizens to take ownership of the space, promoting continuous vitality over time and a greater sense of security. It can be understood as the coexistence of different elements, which can be divided into three subgroups: the functional, social and morphological mixite.	+	+ +
	Functional mix by building type		+	+ +
	Spatial flexibility		+	+ +
Recirculation of resources and self-sufficiency	Water recovery and management	Reduction of waste and optimization of systems to improve water efficiency and accessibility, such as the installation of devices to limit domestic water consumption, such as aerators, flow reducers and thermostatic mixers, or to recover and reuse nutrients from from waste water for agricultural uses, collection and drainage systems and rainwater purification etc.	+ + +	+ +
	Waste recovery and management	Decrease in waste production and management, with an increase in the recycled share, through the collaboration of citizens and the facilitation of collection and sorting operations.	+ + +	+ +
	Self-sufficiency (self-production of food)	Set of strategies and actions to deal with the food emergency, with the aim of reducing food waste and producing good quality food with zero impact.	+ + +	+ +
	Recovery and reuse of demolition material	Building materials stored and reused on site, cutting consumption and CO2 production due to transport	+ + +	+ + +
Sustainable mobility	Improvement of public transport	Regenerate infrastructures and therefore the urban fabric with adaptation and mitigation measures, which must allow accessibility to places over short distances and/or in a short time, including through new generation vehicles such as electric and methane buses, electric cars and trucks, etc.	+ +	+ + + +
	Bike car sharing services	Implementation of sharing mobility such as through dedicated apps, including vehicle rental, in 'free-floating' or 'station based' solutions, parking for bicycles or other vehicles related to light mobility.	+ +	+ + + +
	Increase in cycle and pedestrian traffic	A greater propensity to spread the use of cycle-pedestrian paths to reclaim public spaces and which must not be finalized as the only solutions to have zero emissions.	+ +	+ + + +
	Multimodal hub	All mobility locations are redesigned to be able to receive multimodal transport starting from new stations to interchange places, to a new public transport offer.	+ +	+ + + +
Urban greening, "green and gray" CO2 subtraction	Increase in green area	The vegetation component within the urban fabric is enhanced, contributing to the strengthening of ecosystem services, contributing to the decarbonisation and increase in the resilience of urban settlements, thanks to the ability to subtract carbon through the photosynthesis processes of the tree and shrub masses	+ + +	+ + +
	Urban forestry/reforestation	Urban forestation and reforestation interventions contribute to improving air quality, thermo-hygrometric well-being, the reduction of heat islands and the absorption of climate-altering gases, mainly carbon, from the atmosphere.	+ + + +	+ + +
	Green Infrastructure	Set of urban green solutions such as parks, tree-lined avenues, etc. which contribute, in addition to the absorption of CO2, to counteract the heat island effect in summer. Greenery offers space for leisure, sport, play, meeting, relaxation and nature, contributes to the health of the inhabitants, cools the city in summer, helps prevent floods and increases biodiversity.	+ + + +	+ + +
	CO2 subtraction systems	Set of actions with the primary aim of storing large quantities of carbon from the atmosphere in places where the concentrations of climate-changing gases are high.	+ +	+ + + +

Legend

+	**Low** impact solution adaptive/mitigative) 0.34	+++	**Medium** impact solution (adaptive/mitigative)
++	**Moderate** impact solution (adaptive/mitigative)	++++	**High** impact solution (adaptive/mitigative)

Fig.6 Catalog of the types of solutions to be adopted (mitigative-adaptive)

Urban infrastructures, transport, systems of water, sanitation and energy supply, are constantly and increasingly problematically compromised extreme events, resulting in economic losses,
disruptions of services and negative impacts on well-being. Scientific evidence unambiguously indicates that action needs to be taken much more to keep our planet livable: limiting global warming temperature at 1.5 °C requires rapid, deep reductions and long-lasting global greenhouse gas emissions.
Approaches, addresses, strategies, actions, whereas, using the most frequently used key terms at international level, are attributable to (Tucci, 2023; Newman, 2023; Moreno, 2024):

1. energy transition with renewable energy and net zero carbon technologies;
2. bio-climate responsiveness and especially with biophilic urbanism, permaculture and nature based-solutions;
3. functional mixitè and proximity, in this way first the *Cities of 15 mins* concept;
4. Resources circularity and self-sufficiency by regenerative ecosystems and circular economy;
5. sustainable mobility with attention to electromobility, micromobility, walkability and active transport;
6. urban greening, green CO_2 subtraction; gray CO_2 subtraction and storage.

The renewal Architectural and urban according to the Green City model the approach aims to improve, recover and reuse the heritage by adopting an integrated approach through measures aimed at increasing characters, performance and behaviours ecological, energy and bioclimatic of buildings and urban districts (Tucci, 2021). It seems essential to understand the great contribution that this approach makes in the new design (Alvira Baeza, 2018). First, a distinction must be made between adaptive-climatic measures and mitigative-climatic measures:

- Adaptive-climatic measures are defined as the set of actions aimed at preventing or minimizing the damage that can be caused by the adverse effects of climate change, or exploiting the opportunities that may arise. Examples of adaptation measures are large-scale infrastructure changes, such as building defenses to protect against rising sea levels, or small-scale such as behavioral changes, such as reducing food waste by individuals. In essence, adaptation can be understood as the process of adapting to the current and future effects of climate change;
- Climate-mitigation measures are defined as the set of actions aimed at reducing the emission of so-called greenhouse gases (GHGs) into the atmosphere. Mitigation is achieved by reducing the sources of these gases, either by increasing the share of renewable energy or by creating a cleaner mobility system, or by enhancing the storage of these gases, by increasing the size of forests. In short, mitigation is a human intervention that reduces the sources of greenhouse gas emissions and/or strengthens sinks.

What increasingly defines the creation of the Positive Energy Districts is the dual strategic direction: adaptive and mitigative. These strategies, increasingly necessary and evident, are implemented in consideration of places, environmental contexts, construction technologies. Starting from these considerations and in line with what scientific research in the field of urban planning and technology is developing, the examples (already mentioned above) were observed that contain a series of adaptive and mitigative parameters and criteria that will have to be implemented in urban regeneration, and which will be summarized below in the table.

6. Conclusions

As Peter Newman reminds us "There is now a plethora of large renewable energy projects outside cities with a need for massive expenditure on large transmission systems. So, we need to think about the scale and scope of our urbanism based on net zero technologies. How do we best support the net zero city transition? Do we enable a bottom-up policy approach based on local place and local management or a top-down policy approach which is trying to build big scale net zero grids with no serious local systems? This conflict will need to be better understood as I believe this is turning into a major conflict between two ways of thinking about cities

which has been well known to those of us involved in urban planning traditions: the conflict between modernism and historic urbanism".

The PED are enabling progress to be made and new technologies to be tested. But they are not enough: the energy transition must be a system. To enable the ecological transition of the city, positive energy districts can represent a powerful vector for regenerating entire urban areas and above all putting the economy of self-sustainability back at the center, which is fundamental for communities (Pultrone, 2024; Fistola et al., 2024).

The next strategies to implement the zero-emission city (with the PED approach) will have to focus on the following steps:

- Sustainable cities. City policy, urban planning, sustainable transport, reducing urban sprawl and making the city compact (as Carlos Moreno 15 mins), green and affordable buildings, decarbonizing urban development, biophilic urbanism, 21st century planning tools, water and waste, walkable urban design and sustainability policy;
- Participatory sustainability. New governance models based on collective intelligence (and used by big data), wisdom and power of people for a sustainable planet with sustainable civilizations societies, and communities;
- Green innovation systems. Innovation in technology, renewable energy, value systems, population policy, women and development, structural and cultural changes, new business models and professional activity;
- Resilient Systems. Climate adaptation, coastal sustainability, culture and science-governance dialogue to enable natural systems to perform more sustainably.

It is evident, therefore, that the main challenge of the future is to alleviate the exploitation of natural resources and move towards a re-balance that can be achieved through an intelligent (smart) use of resources, work on the green system (linked to the green economy), open urban systems to inclusiveness or to alleviate inequalities (inclusive), ceasing to wear out the territory through uncontrolled urbanization and optimizing consumption (Foster, 2024; Papa, 2024). Today more than ever, the complexity of the disciplines tends to interact and often to integrate, creating a new plot necessary (also methodological, De Certeau, 1990) for the articulated declination of sustainability in the various transformations, which cannot be achieved without a protean dimension, which contains the needs of the present, the awareness of the past, the experimentation on anticipation, increasingly visionary and holistic (Pidalà, 2014a and 2021b; Volpatti et al., 2024) for the future (Foster, 2024).

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Image Sources

Fig.1: Balance diagram between energy efficiency, energy flexibility and local energy production from

https://www.lumi4innovation.it/positive-energy-district-distretti-energetici/

Fig.2: Case Study_La Fleuriaye (France). Source: Elaboration by the author

Fig.3: Case Study_Hammarby Sjöstad (Sweden). Source: Elaboration by the author

Fig.4: Case Study_Ready, Växjö.(Sweden) Source: Elaboration by the author

Fig.5: Case Study_La Cerisaie, (France). Source: Elaboration by the author

Fig.6: Catalog of the types of solutions to be adopted (mitigative-adaptive). Source: Elaboration by the author

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Problems and restoration strategies of urban mediterranean rivers in Spain

Guadalmedina river as a potential ecological corridor in the green-blue infrastructure of Malaga, Spain

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Abstract
Urban rivers in good hydrological and ecological condition are essential for the ecological connectivity of the territory, connecting fragmented habitats. Additionally, they provide benefits such as flood mitigation, CO2 storage, microclimate regulation, and air quality improvement. They act as natural filters and offer recreational and educational spaces. However, urban development has negatively affected rivers, disrupting their natural dynamics and ecological connectivity due to intense urbanization and infrastructure. The restoration of rivers using ecosystem-based strategies and nature-based solutions is proposed as one solution to address the challenges of climate change. After a literature review and analysis of Mediterranean urban river restoration projects, problems and strategies for their restoration are identified and systematized. The restoration proposal for the Guadalmedina River in Malaga, Spain, is analyzed as a case study. This proposal is relevant for its ecocentric, systemic, and integrated approach from the basin to the urban section, promoting its functionality as an ecological corridor that integrates into the city's green and blue infrastructure and involves the public in the design, execution, and management process of the restoration.

Keywords
Urban river restoration; Green-blue infrastructure; Biodiversity

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1. Introduction

1.1 Importance of urban rivers as ecological corridors in the territory

Urban rivers in a state of good hydrological and ecological condition are dynamic elements crucial for fostering ecological connectivity within the territory, as they can connect fragmented habitat areas, providing routes for fauna and flora that facilitate genetic exchange, species dispersion, and wildlife migration, essential for the survival of many species (Fang et al., 2023; Seddon et al., 2020; Vermaat et al., 2016).

In addition to their ecological function, these rivers provide numerous environmental and social benefits that are vital for human well-being and urban resilience (Gómez-Baggethun & Barton, 2013). Essential ecosystem services such as flood mitigation by increasing permeable drainage surfaces, and CO2 absorption and storage by incorporating green areas, are some of the benefits. Moreover, they regulate the microclimate, reduce the urban heat island effect, and improve air quality. Riparian vegetation also acts as a natural filter for stormwater and wastewater, reducing pollutant loads and enhancing water quality (Bernhardt et al., 2007; Graviola et al., 2022; Mitsch & Gossilink, 2000). At the same time, it is important to consider their balanced distribution in the city (Mobaraki, 2023; Pantaloni et al., 2024). From a social perspective, rivers can provide recreational and educational public spaces and revitalise degraded urban areas (Chiesura, 2004; McPhearson et al., 2016), and be planned on the basis of co-governance (Scheiber & Mifsud, 2024).

1.2 Deterioration of river ecosystems

Many cities worldwide have been established and developed around rivers due to the resources they provide, such as water availability, transportation, food, energy, etc. (Habersack et al., 2015). However, rivers are natural systems that have been profoundly affected by the exponential growth of cities, especially since the second half of the 20th century, with intensive urbanisation and urban planning disconnected from their territories.

The river space has been progressively occupied and filled with urban constructions and linear infrastructure such as roads and railways. The continuous human impact and control of natural characteristics have been executed through hydraulic and engineering approaches such as the construction of dams, reservoirs, levees, etc., or the channelisation, or even diversion, of river courses to prevent urban flooding (Du et al., 2020; Giovinazzi & Giovinazzi, 2011; Jing et al., 2019). Other issues are associated with land-use changes, agriculture, or deforestation often carried out in river basins. These anthropogenic pressures fragment rivers and habitats, greatly disrupting or diminishing river dynamics, hydrological and ecological connectivity (Booker, 2002; González del Tánago & García de Jalón, 2011; Gurrutxaga San Vicente & Lozano Valencia, 2012; Skoulikidis et al., 2016; Tockner et al., 2010). They restrict the mobility space of rivers and isolate channels from their natural floodplains, impeding or hindering the processing of materials and energy in any of the three directions necessary for their good ecological functioning - upstream to downstream, between the river channel and its floodplain, and between the riparian zone, hyporheic zone, and adjacent groundwater.

Often, rivers end up being converted into wastewater drains and waste dumping areas (Gumiero et al., 2013; Ministerio para la Transición Ecológica y el Reto Demográfico, 2023; Vannote et al., 1980). Therefore, all these anthropogenic pressures have affected, to a greater or lesser extent, the structure and ecosystem functioning of rivers, generating a series of common problems that have been systematised like finding.

1.3 Challenges and opportunities for urban rivers in the face of climate change

In the current context of global climate change, cities are experiencing increasingly extreme weather conditions and face numerous environmental, social, and economic challenges, such as heat waves, air pollution, torrential rains, floods, and sea level rise (Bai et al., 2018; Intergovernmental Panel on Climate Change, 2023).

Mediterranean cities are particularly affected and vulnerable to these extreme phenomena (Galderisi & Profice, 2012).

On the other hand, Mediterranean urban rivers face a number of concrete challenges:

- An overall planning framework that integrates the natural dynamics of rivers with sustainable urban development, connecting green and blue areas to generate climate resilience;
- Integrated river planning and management models that include multiple variables (ecology, risks and usability) and involve multi-stakeholder collaboration, aligning with the concept of a 'river contract';
- Sustainable economic processes based on ecosystem strategies that prioritise adaptation to climate change over rigid and costly infrastructures.

Urban nature is therefore crucial for addressing sustainability challenges. The restoration of rivers offers an opportunity to implement natural strategies to reverse the anthropogenic impacts they are affected by, mitigate and prevent the negative effects generated by climate change, and even turn these problems into improvements for the territory and cities, acting as ecological corridors that facilitate the movement of species and the flow of genes between fragmented ecosystems.

There is a growing scientific literature on the integration of rivers into urban planning to maximise their ecological and social benefits, and on understanding the role of urban rivers as ecological corridors (Francis, 2013; Johnson et al., 2019). Following a literature review, it appears that in recent decades there has been a paradigm shift in the management of stormwater and river spaces, from an anthropocentric approach dominated by hard engineering solutions aimed at controlling water dynamics, to a more ecosystem-based approach with multifunctional strategies designed to restore ecological processes and with ecosystem-based approaches (EBA) (Wu, 2014) and nature-based solutions (NbS). In this new approach, the preservation and/or restoration of rivers is considered the best way to address the increasing risks posed by climate change. These natural strategies are a more effective and economical alternative, providing more functions and benefits, and require slower timescales in line with natural processes, as they support and align with the proper ecosystem functioning of the riverine territory.

Unlike previous approaches to river interventions that created a fixed geometry and image of the river or focused on specific individual objectives, such as fishing, understanding the river as a resource or as a problem, it is now understood that rivers are complex systems that must be addressed from different dimensions. The Italian Centre for River Restoration (2017) proposes river restoration as an integrated and synergistic set of various actions and techniques (legal, administrative, financial, structural), allowing for the restoration of the natural processes of the river system and, consequently, its functional characteristics (geomorphological, physico-chemical, and biological). This approach aligns with a systemic approach proposed by both the New Urban Agenda and the United Nations Sustainable Development Goals (United Nations, 2015) to address the challenges of climate change in cities (González del Tánago & García Del Jalón, 2007; Ministerio para la Transición Ecológica y el Reto Demográfico, 2023).

River restoration can be approached at different scales of intervention, each with its own specific focus and objectives. At the basin level, the goal is to manage and restore the hydrological and sedimentary processes that affect the entire river system, ensuring an integrated and sustainable approach. At the reach scale, the intervention focuses on specific sections of the river, addressing local issues such as bank erosion or disconnection from floodplains. At the substrate level, restoration targets the improvement of the riverbed, promoting habitat diversity for aquatic species by rehabilitating sediments and water flow. Collectively, ecological restoration aims to recover river processes and the natural dynamics of the river, focusing on reconstructing the existing river ecosystem before its deterioration, in order to restore its original functionality and biodiversity (González del Tánago & García Del Jalón, 2007; Cialdea et al., 2022).

This new approach and sensitivity also demand the integration of the public in river restoration processes. It recognises that humanity is part of nature and that social demands must be considered and addressed fairly

in the process (Linton & Budds, 2013), and that human presence must be taken into account in constructing an environmental quality benchmark for these rivers (González del Tánago & García de Jalón, 2011; Lazzarini et al., 2024). River restoration has also become a widely accepted social goal in developed countries, as a restored river is not only healthier in terms of ecosystem elements but also more sustainable in its social functions.

After analysing urban river renaturalisation projects in the Mediterranean context, there are very few examples where restoration has been implemented at the basin level and in a systemic manner (see Tab.1), with the river functioning as an ecological corridor, and simultaneously connected with other biological spaces in the city. A successful example of ecological restoration in the Segura river basin are the LIFE+ Segura Riverlink and LIFE+ Ripisilvanatura projects (Oliva-Paterna et al., 2015), implemented between 2013-2017 and 2014-2019, respectively, by the Confederación Hidrográfica del Segura (CHS) with the collaboration of local institutions. Segura Riverlink focused on the renaturation of the river by removing artificial barriers, restoring habitats and improving ecological connectivity. Ripisilvanatura focused on the recovery of the riverbank forest, controlling invasive species and restoring priority habitats such as willow and poplar forests, actively involving local communities in both cases to ensure long-term sustainability. This work uses the case study of the Guadalmedina river restoration proposal in Málaga carried out by Rizoma Foundation[1], which incorporates ecosystem-based strategies, integrating the river as an ecological corridor in the city's green and blue infrastructure, and through a participatory process in the design, execution, and management of nature-based proposals. Due to its systemic and comprehensive nature and its alignment with the new ecosystem-based paradigm, it can help inform policy actions for the restoration of this river, or others with similar characteristics in the Mediterranean region.

Component	**Description**
Ecological	Recovery of the ecological functionality of the river system: ecosystem connectivity, water quality and climate resilience.
Social	Recognition of the river as a common good. Integration of local communities in management through participatory processes in the design, implementation and monitoring of proposals.
Economic	Balance between ecological restoration and local economic activities, promoting sustainable practices and long-term benefits.
Key interactions	Relationship between the river, its watershed and human activities, considering cross-impacts and seeking synergies in restoration efforts.
Systematisation by scale	- Local scale: Restoration of urban sections of the river, integrating ecological corridors into urban infrastructure. - Basin scale: Catchment-wide management to improve connectivity, water quality and habitat recovery. - Regional scale: Linking strategies with Mediterranean policies to develop scalable and adaptable restoration models.
Restoration strategies	- Hydrological restoration: Improving water retention and flow regulation. - Ecological connectivity: Restore natural corridors and habitats. - Community-based management: Fostering participatory governance.
Nature-based solutions	Application of natural approaches to river management, such as wetland restoration and reforestation, integrating the river as an ecological corridor within the city's green and blue infrastructure.
Regulatory framework	Alignment with Spanish and European regulations for river restoration, such as the Water Framework Directive and nature restoration policies.

Tab.1 Systemic approach

[1] Rizoma Foundation is an entity dedicated to the critical, analytical, and creative research of the territory and cities—from architecture, urbanism, and urban geography— with special attention to the geographical area known as ZoMeCS (Metropolitan Zone of the Costa del Sol)

2. Objectives and methodology

The main objective of this work is to explore and analyse the role of Mediterranean urban rivers and the opportunity for their restoration as ecological corridors integrated into the green and blue infrastructure of cities, helping to mitigate the effects of climate change. Current issues of urban rivers are identified, and strategies for their ecosystemic restoration are studied. The case study focuses on the restoration proposal for the Guadalmedina River in Malaga (Spain).

To achieve this, a phased methodology has been designed as shown in Tab.2:

- PHASE 1: Literature Review. A bibliographic and scientific literature study on urban rivers has been conducted, identifying the most relevant themes and issues related to the restoration of urban rivers.
- PHASE 2: Identification, Characterisation, and Systematisation of Common Issues and Proposed Strategies to Address Them. Evaluation of river renaturalisation projects within the Mediterranean context in Spain.
- PHASE 3: Case Study: Guadalmedina River Restoration Proposal. The proposal is explained, analysed, and systematised by scales, and its suitability is assessed and discussed within the framework of an integrated ecosystemic approach and in relation to the identified restoration strategies.
- PHASE 4: Extraction of specific actions according to the problems and general strategies detected.

Main phases	**Sub-Phases**	**Description**
1. Literature Review	1.1 Urban rivers as ecological corridors	Benefits: Connectivity with fragmented habitats | Flood mitigation | CO2 absorption | Microclimate regulation | Natural filter for rainwater and wastewater | Recreational and educational spaces for the public
	1.2 Deterioration of river ecosystems	Issues: Urban developments | Large infrastructures | Changes of use in the river basins
	1.3 Urban rivers rol in the face of climate change	Aim: Systemic approach | Restoration of ecological processes | Ecosystem-based approaches (EBA) | Nature-based solutions (NBS) | Integration of citizens in river restoration processes
2. Identification, Characterisation, and Systematisation	2.1 Selection of case studies	Selection of river through project, location, intervention in urban section or basin.
	2.2 Comparative	a) Isses: Alteration of the hydrological flow regime | Geomorphological modification | Loss of biodiversity | Water management problems | Flooding | Pollution | Landscape and recreational degradation | Lack of comprehensiveness | Lack of collaboration and difficulty in management b) Strategies: Restoration of the natural hydrological regime | Geomorphological rehabilitation | Revegetation and habitat restoration | Integrated water management | Flood risk reduction | Improvement of water quality | Promotion of recreational and educational use | Comprehensiveness and territorial function | Collaboration and Co-governance
	2.3 Identification of the most representative case	Analysis of the project that develops the issues and strategies of the previous phase in a more systemic way.
3. Guadalmedina River Restoration Proposal	3.1 Start point	a) Basin: Pollution of the river due to the discharge of waste water from streams. It has two sections as Sites of Community Importance (SCI) due to the presence of species protected by Directive 92/43/EEC. b) Agujero and Limonero Dams: The dam poses a threat due to its location in clayey soil and does not eliminate the risk of flooding. There are a large number of neighbourhoods built directly on the flood plain of the river. c) Urban section: Blockage of the natural flow of the river by the construction of the dam or the channelling of the river channel.
	3.3 Proposal	a) Basin: Reintroduction of riparian vegetation, restoration of meanders and wetlands, and creation of flood zones.

		b) Urban section: Opening of the dam, modification of the canal section and incorporation of riparian vegetation. c) Green and blue infrastructure: Analysis and integration of the rivers with other existing green spaces or those susceptible to renaturalisation in the urban and peri-urban environment.
4. Assessment and identification of actions	4.1 Strategies and actions	Specific strategies and actions are extracted for each general strategy. This can be a toolbox for future river action projects.

Tab.2 Phases of the methodology

3. Systematisation and study of issues and strategies for the restoration of urban rivers in the mediterranean context

For the study of urban river renaturalisation projects in the Mediterranean context, nine cases of Spanish rivers have been selected as shown in Tab.3: 1. Guadalmedina, 2. Oro, 3. Manzanares, 4. Genil, 5. Isuela, 6. Castaños Galindo, 7. Cadagua, 8. Vinalopó, and 9. Besós. For each of these rivers, their location and length have been identified, along with the scope of the interventions undertaken, the current status of the proposals, and the references from which the analyses have been conducted.

River	Location	Scope	State	Reference
1. Guadalmedina (51,2 km)	Málaga (Andalucía)	Integral: River Basin and Urban Section	Project	(Fundación Rizoma, 2011)
2. Oro (13,6 km)	Melilla (Ciudad autónoma de Melilla)	Partial: Urban section	In progress	(Ecologistas en Acción, 2016)
3. Manzanares (92 km)	Madrid (Comunidad autónoma de Madrid	Partial: Urban section	In progress	(Área de Gobierno de Medio Ambiente y Movilidad - Ayuntamiento de Madrid, 2016)
4. Genil (359 km)	Granada (Andalucía)	Partial: Urban section (7.4 km)	Project	(Ecologistas en Acción, 2019a)
5. Isuela (44 km)	Huesca (Aragón)	Partial: Urban section (1.45 km)	Project	(Ecologistas en Acción, 2019b)
6. Castaños-Galindo	Barakaldo (Pais Vasco)	Partial: Urban section (3,11 km)	Project	(Ecologistas en Acción, 2019c)
7. Cadagua (70 km)	Barakaldo (Pais Vasco)	Partial: Urban section (5 km)	Project	(Ecologistas en Acción, 2019c)
8. Vinalopó (96,5 km)	Elche (Alicante)	Partial: Urban section (2,5 km)	Project	(Ecologistas en Acción, 2020)
9. Besós (17,7 km)	Barcelona (Cataluña)	Partial: Urban section (4,3 km)	In progress	(Àrea Metropolitana de Barcelona, 2023)

Tab.3 Renaturation projects analysed

Based on the literature review, national and European regulations, and projects on the renaturalisation and restoration of Mediterranean rivers, a series of common issues have been identified following the pressures and impacts discussed in section 1. These have been grouped into nine general thematic frameworks: 1. Alteration of the hydrological flow regime, 2. Geomorphological modification, 3. Loss of biodiversity, 4. Water management issues, 5. Flooding, 6. Water pollution, 7. Landscape and recreational degradation, 8. Lack of integration and collaboration, 9. Difficulty in management and collaboration, and 10. Relationship to planning systems.

Correspondingly, using the same methodology, all proposed actions to address these issues have been identified and grouped into nine ecosystem-based strategic frameworks as shown in Tab.4, considered necessary to approach integrally and synergistically to achieve appropriate restoration of urban rivers as ecological corridors: 1. Restoration of the natural hydrological regime, 2. Geomorphological rehabilitation, 3.

Revegetation and habitat restoration, 4. Integrated water management, 5. Flood risk reduction, 6. Improvement of water quality, 7. Promotion of recreational and educational use, 8. Integration and territorial function, 9. Collaboration and co-governance, and 10. Contrast or Integration with current plans.

Issues	Strategies	1	2	3	4	5	6	7	8	9
Alteration of the hydrological flow regime	Restoration of the natural hydrological regime	✓	✓	✓	✓	✓	-	-	✓	✓
Geomorphological modification	Geomorphological rehabilitation	✓	✓	✓	✓	✓	-	-	✓	✓
Loss of biodiversity	Revegetation and habitat restoration	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water management problems	Integrated water management	✓	-	-	-	-	-	-	-	-
Floodin	Flood risk reduction	✓	-	-	-	-	✓	✓	-	-
Pollution	Improvement of water quality	✓	-	-	✓	✓	-	-	✓	✓
Landscape and recreational degradation	Promotion of recreational and educational use	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lack of comprehensiveness	Comprehensiveness and territorial function	✓	-	-	-	-	-	-	-	-
Lack of collaboration and difficulty in management	Collaboration and Co-governance	✓	-	-	-	-	✓	✓	-	-
Relationship to planning systems	Contrast with current plans	✓	-	-	✓	✓	✓	✓	✓	-
	Integration with current plans	-	✓	✓	-	-	-	-	-	✓

1. Guadalmedina | 2. Oro | 3. Manzanares | 4. Genil | 5. Isuela | 6. Castaños Galindo | 7. Cadagua | 8. Vinalopó | 9. Besós

Tab.4 Summary of conceptual issues and strategies extracted from the projects analysed

It is important to highlight that most of the projects focus on interventions limited to urban sections of the river, rather than encompassing the entire river basin. Additionally, none of these projects comprehensively address all restoration strategies, except for the proposal concerning the Guadalmedina River, which is analysed in depth as a case study in this work.

In most cases, the proposals are based on the premise of the impossibility of returning to the pristine natural conditions of the river and do not propose a systemic river restoration, but rather a renaturalisation understood as the recovery of naturalness of the urban section within the possibilities that exist in each city. These actions, such as revegetating the riverbanks, provide environmental and landscape benefits for cities that are increasingly valued and demanded by citizens. However, it is difficult to find renaturalisation projects approached systematically at the basin level, which would restore the river's function as an ecological corridor connecting ecosystems before and after the urban section of each city.

According to Kondolf (2011), the most effective approach to river restoration is to allow them to "heal themselves" by facilitating the physical processes of flooding, sediment transport, erosion, deposition, and channel change to create and maintain complex river forms. However, one of the greatest challenges of this approach in urban sections, most of which are channelised, is the space required for the river to move in all three spatial directions and sufficiently recover the flow regime and sediment load.

It has been proven that a "process-based river restoration", which focuses on correcting anthropogenic disturbances and promoting self-restoration with minimal corrective actions, allows the fluvial system to develop its own morphology and enhances its resilience capacity (Díaz-Redondo et al., 2022; Vermaat et al., 2016). An interesting example is the Manzanares River as it passes through the city of Madrid, where a renaturalisation plan proposed to permanently open the dams in its urban section. By achieving a constant flow of water, although the river remains channelised, it has recovered part of its original dynamics and improved, to some extent, its hydrological and ecological functioning, and has regained landscape, cultural, and social functions. This approach aligns with the objective proposed by some authors (Pires Veról et al., 2019), who understand that environmental recovery cannot reach the original natural characteristics of the

river, but can improve it compared to the current situation of the river, not aggravating its current state of degradation and reversing, as much as possible, the degraded conditions.

4. The Guadalmedina River in Malaga as a case study

4.1 Guadalmedina, the city river

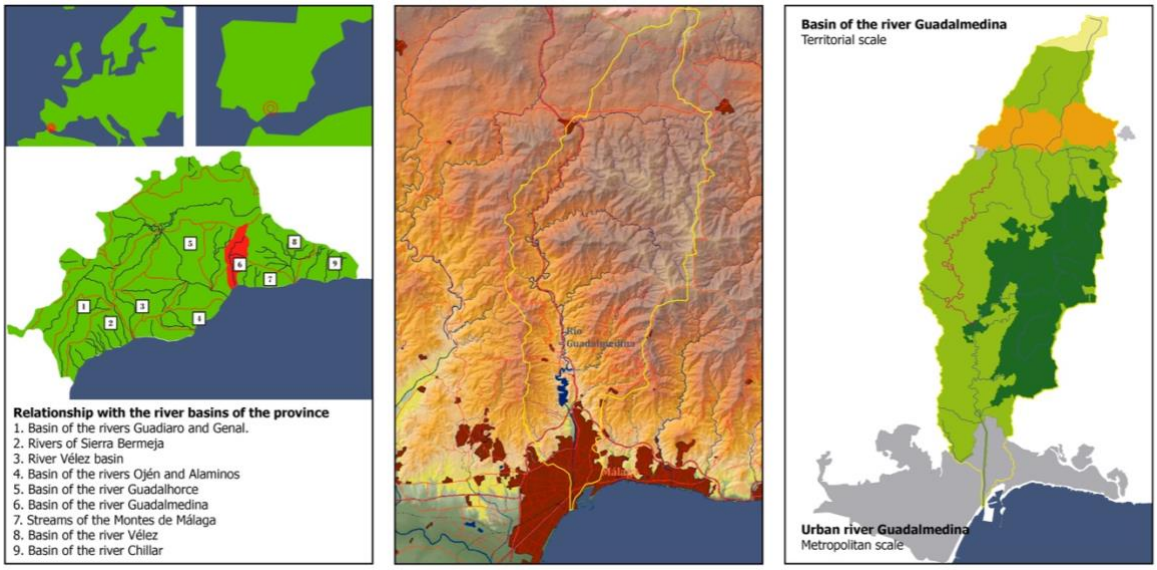

Fig.1 Location of the Guadalmedina river in Malaga, Spain

The relationship between the city of Malaga and the Guadalmedina River has been complex and changing. Initially, the city was established at the estuary of the Guadalhorce River and later moved to the mouth of the Guadalmedina, giving rise to present-day Malaga and shaping its identity.

Deforestation of the river basin for agricultural use increased runoff and sedimentation, which facilitated overflows and led to recurrent and disastrous floods (such as the one in 1661 that caused 601 deaths). Over the centuries, measures were implemented, all engineering in nature, to mitigate these problems, such as lowering the riverbed or channeling the river in 1876, which significantly altered its course and ecology.

The great flood of 1907 prompted the construction of the Agujero reservoir and a shift in focus, centering the solution at the source of the problem through the reforestation of part of the river basin to combat desertification and erosion. In 1919, the Guadalmedina Basin Correction and Reforestation Project was agreed upon, partially executed with 5,000 hectares between 1930 and 1980, which improved flood control and allowed the creation of the Montes de Málaga Natural Park in 1989. Despite these efforts, the reforestation remains incomplete, and over 7,000 hectares are still pending.

4.2 Characterisation and identification of pressures and impacts of the Guadalmedina river

Territory of the river basin: The river basin of the Guadalmedina River, covering an area of 180 km², is located in the north of Malaga province, encompassing the municipalities of Antequera, Casabermeja, Colmenar, and Malaga. The Guadalmedina River features a subtropical pluvial regime and torrential dynamics, resulting in a seasonal hydrological pattern with significant flows in winter and dry conditions in summer. It originates from a karst spring at an altitude of 1,306 meters and flows for 51 km through various habitats, including forests, scrublands, and agricultural areas, traversing the Montes de Málaga Natural Park until it reaches the Limonero

dam. From the dam, the river is channeled for its final 7 km, forming the urban section of the city of Malaga, until it discharges into the Mediterranean Sea, where the port of Malaga is located in its floodplain.

The water quality of the river deteriorates upon entering Malaga due to contamination from untreated wastewater from converging streams. Nevertheless, the Guadalmedina River holds significant environmental value, with notable biodiversity of flora and fauna, including several species of birds, mammals, and plants that rely on the river and its margins for survival. It still preserves natural sections that could serve as habitats for various species. Additionally, it has two sections in its upper and middle basin designated as Sites of Community Importance (SCI) due to the presence of species protected under Directive 92/43/EEC.

Agujero and Limonero Dams: Subsequent studies revealed that the Agujero Dam (located 9 km from the river's mouth) did not eliminate the risk of flooding. Consequently, the Limonero Dam was constructed in 1983 (2 km downstream) to regulate the flow of the Guadalmedina River and supply water to the city. These dams have controlled the river's flow regime to this day. The dam's location on clayey terrain, just 500 meters from the first buildings of a city with 550,000 inhabitants, poses a significant threat, as it is a gravity dam constructed with loose materials.

The channel in the 7 km urban section borders 16 neighborhoods with different social, economic, and urban characteristics. Along this route, the river initially restrained urban expansion toward the western part of the city until it succumbed, primarily due to construction pressure, resulting in intensive urban development, as evidenced by the number of neighborhoods built directly on the river's floodplain.

Urban section: This urban section is rendered ineffective in its hydrological and ecological functions as a river, with the flow regime altered by the dam. The entire stretch is channeled between stone and concrete walls, with the final 1.5 km having a concreted riverbed.

This anthropization and profound modification caused by transverse or longitudinal artificial barriers that block the river's natural flow, such as the construction of the dam or the channelization of its course, have led to several issues: water pollution, habitat degradation and fragmentation, discontinuity in the three spatial axes, and disconnection from its natural environment. The present vegetation consists of ruderal grassland with a proliferation of various invasive exotic species. From a social and landscape perspective, it is an environmentally and aesthetically neglected corridor in the city center, with limited use and accessibility.

4.3 Proposal for ecosystem restoration and integration into green infrastructure

The proposal by the Rizoma Foundation aims to potentially restore the fluvial ecosystem of the Guadalmedina River. The scope of analysis, diagnosis, and proposals has not focused solely on the channel of its urban section but has been approached systemically, considering the entire river basin territory. The proposal's design was carried out by an interdisciplinary team and developed in different phases: 1. River characterization (study of the basin, ecological function, and ecosystem services), 2. Diagnosis and evaluation (diagnosis of physical and biological conditions, assessment of the river basin's potential as a biological corridor, and integration of the urban section), and 3. Proposal design through the determination of strategies and actions (proposal plan and comprehensive management integrating ecological, social, and economic aspects, promoting the participation of citizens and various interested stakeholders).

For the collaborative process of developing the proposals, various actions have been carried out over time: classes and lectures by specialists; field studies on the characteristic ecosystems of the basin with the collection of environmental and biological data; multidisciplinary workshops involving students, technicians, groups, and associations; agent mapping; expert interviews; surveys; awareness workshops in educational centers; and the study of satellite images and the use of GIS. In parallel with the design process, a pedagogical effort has been made to raise awareness about the environmental, social, and cultural (identity, heritage) values of urban rivers.

The restoration proposal is based on the determination of strategies by dimensions: a) Fluvial dimension: Forestry and hydraulic-hydrological solutions, b) Heritage dimension: Identity, heritage, and equipment, c) Economic-financial dimension, d) Legal dimension. However, this research focuses on the fluvial dimension, with forestry and hydraulic-hydrological solutions as the main elements of river restoration as a biological corridor. In this work, due to space limitations, only the fluvial dimension is addressed, focusing on forestry and hydraulic-hydrological solutions.

It is worth mentioning that the project proposed by the Rizoma Foundation does not suggest a formalization of the proposed strategies; instead, actions are gradually formalized through collective consensus with the community, associated with a pedagogical process over time, according to needs, demands, and economic resources. It does not propose a closed technical project, but a series of activities over time as participatory mechanisms that operate as dynamic tools for the co-creation of solutions. The impact of the solutions is continuously evaluated through a system of indicators that allows the strategies to be adjusted and reconfigured according to their effectiveness and the fulfilment of the objectives. An adaptable and evaluable model is proposed, with the capacity to generate synergies between the actors involved and to maximise the potential of the territory in environmental, social and economic terms.

Territory of the river basin: The proposed approach at the river basin level is to carry out hydrological-forestry reforestation (Fig.2 and Fig.3), respecting the more traditional land uses, such as agriculture, in areas where it is more deeply rooted and serves as an economic livelihood for the population. It is proposed to undertake actions in areas with sufficient natural potential and those degraded by traditional agricultural use, which currently do not have a defined purpose. The species used for reforestation would include a mix of broadleaf and pine trees, along with typical Mediterranean shrub species, with the aim of restoring the area's potential vegetation according to bioclimatic series, improving forest management, and expanding the recreational uses of the basin. Hydrologically, the reforestation would decrease flood risk by reducing peak flows during the intense rains typical of the Mediterranean climate and increasing the response time to these events. Additionally, the vegetation would increase rainfall interception, reducing erosion and sediment transport to the reservoir, thus stabilizing the soil and slopes.

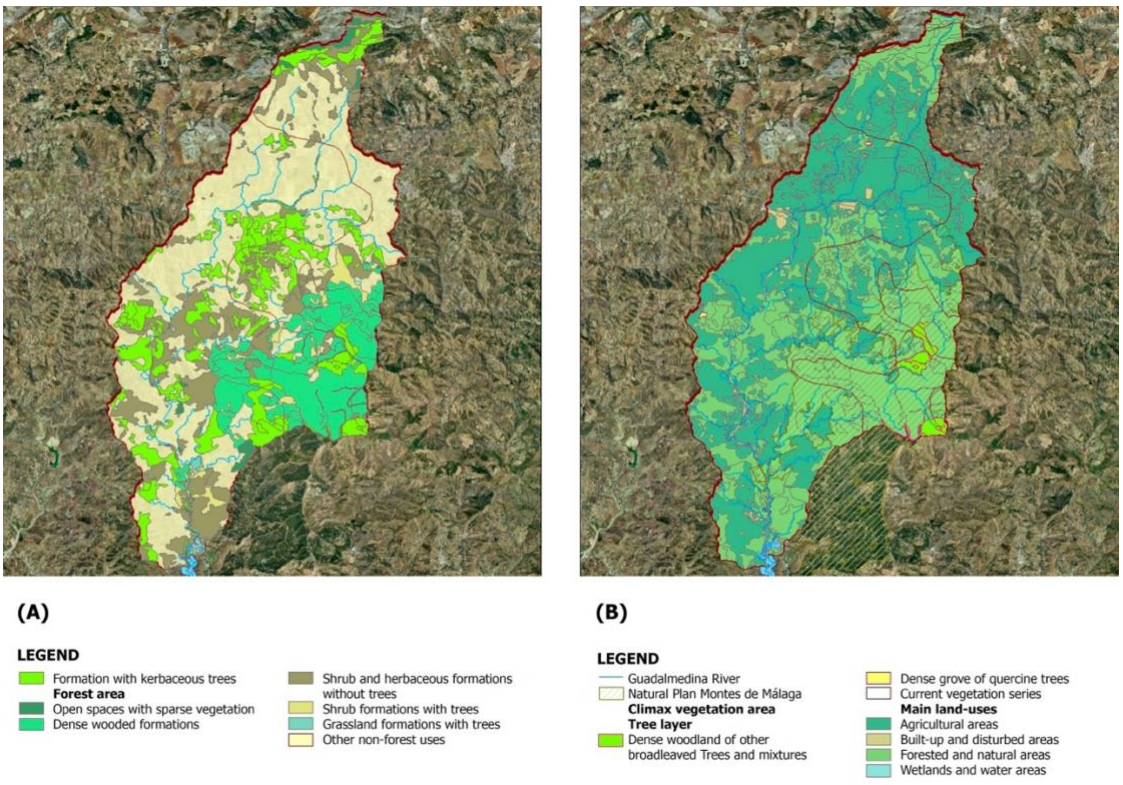

Fig.2 (A) Current vegetation of the Guadalmedina river basin and (B) Potential vegetation of the Guadalmedina river basin

The intervention proposals include the reintroduction of riparian vegetation, the restoration of meanders and wetlands, and the creation of controlled flood areas to mitigate flood risks and promote biodiversity by providing habitats for various species that depend on this ecosystem (Gomes Miguez et al., 2012). The basin presents a high potential for transforming the river into an ecological corridor due to its central position in the territory, allowing it to act as a link between the contiguous sub-basins of the Jabonero and Guadalhorce rivers through the various tributaries of the Guadalmedina. This route preserves numerous elements of hydraulic heritage, such as mills and an aqueduct, which are proposed to be restored and managed appropriately.

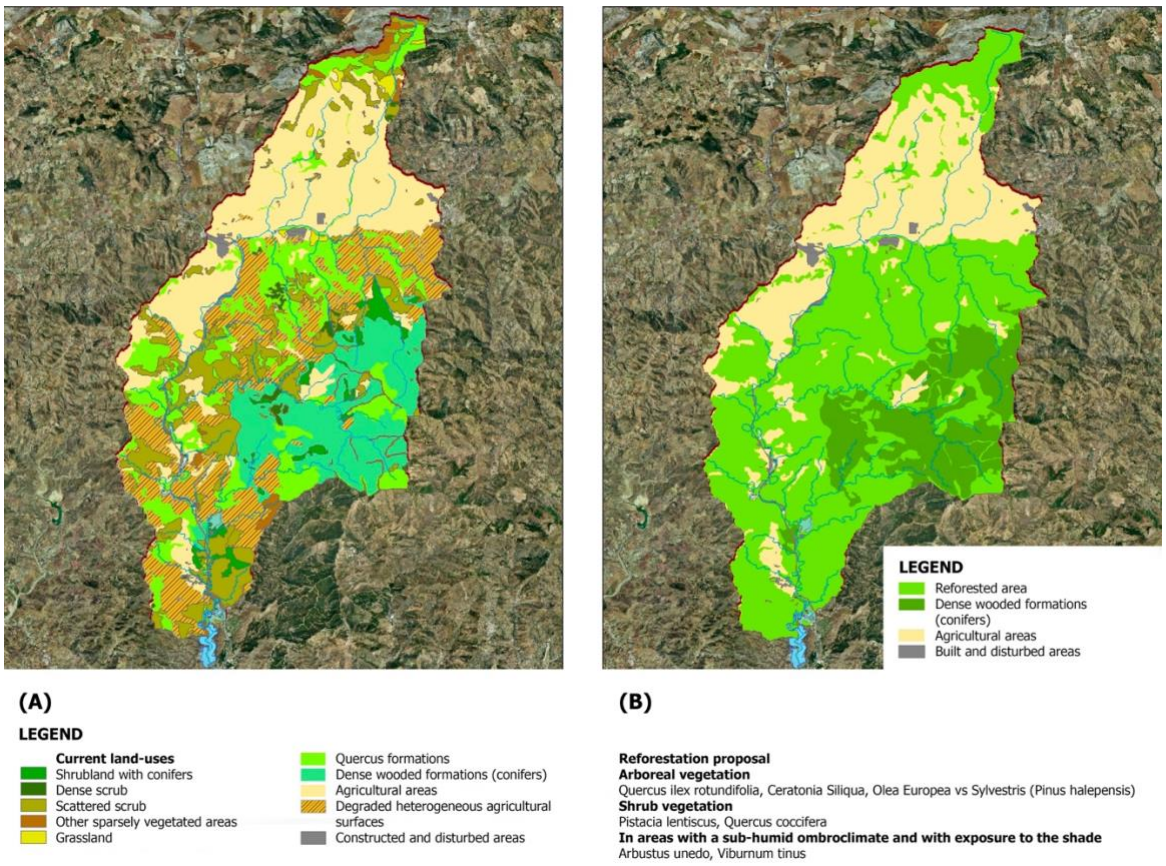

Fig.3 (A) Current land-uses in the Guadalmedina river basin and (B) Climax status of the Guadalmedina river basin

Urban section:

- Opening of the Dam. A study of the Limonero Dam is conducted, comparing different intervention possibilities based on its operation, as well as its potential removal. It is proposed to open the dam permanently so that all the water from the Guadalmedina River at this point, which amounts to 15 hm^3 annually, is allocated to provide the ecological flow;
- Modification of the Channel Section. A modification of the channel sections is proposed, changing the geometry to a configuration more analogous to the natural terrain forms (Fig.4 and Fig.5), attempting to provide maximum river space while respecting the low-water channel or main drainage path of the river. Medial bars and islands are incorporated to allow the river flow to split into different channels, creating heterogeneity in the channel and forming a complex of multiple threads. It is proposed to achieve total permeability of the channel by demolishing the existing concrete slab in the final stretch, which is 1,058 meters long. To calculate these new sections, hydraulic simulations were conducted for different return periods to characterize and identify flood-prone areas and promote the reduction of risks associated with river floods;

- Incorporation of Riparian Vegetation. The proposal includes the eradication of exotic and invasive vegetation while preserving the phreatophytic herbaceous vegetation (reed and bulrush) that temporarily appears in the channel. Subsequently, different types of revegetation will be introduced according to the space they occupy in each section of the channel, respecting the natural bands of the channel and the riverbank, allowing effective ecological connectivity, and improving the hydraulic functioning of the flow. After demolishing the walls, topsoil will be applied for profiling and conditioning the new sections, with the introduction of bioengineering techniques, such as coconut fiber mats, for slope retention and to enable subsequent revegetation and/or spontaneous colonization by native riparian vegetation.

Integration into the urban fabric. Green and blue infrastructure: The restoration of the river as an ecological corridor connects the more natural ecosystems of the upper and middle basins, such as the Montes de Málaga Natural Park, with the coastal ecosystem. Since the river traverses the entire urban territory of Malaga over a distance of 7 km, it is used as an ecological connector with other existing green spaces or those susceptible to renaturalization in the urban and peri-urban areas.

The large urban green spaces already existing in the city (Guadalhorce River, Victoria Hill, Gibralfaro Park, etc.) are analyzed as core spaces, and connections with other green spaces functioning as nodes are proposed. These are integrated into a network forming green and blue infrastructure through ecological connectors, with the river as the central ecological corridor, along with other naturalized streets and spaces. The plan is for the river to integrate into the city in such a way that it gradually colonizes all spaces adjacent to the river, such as creating flood zones that mitigate the river's rises.

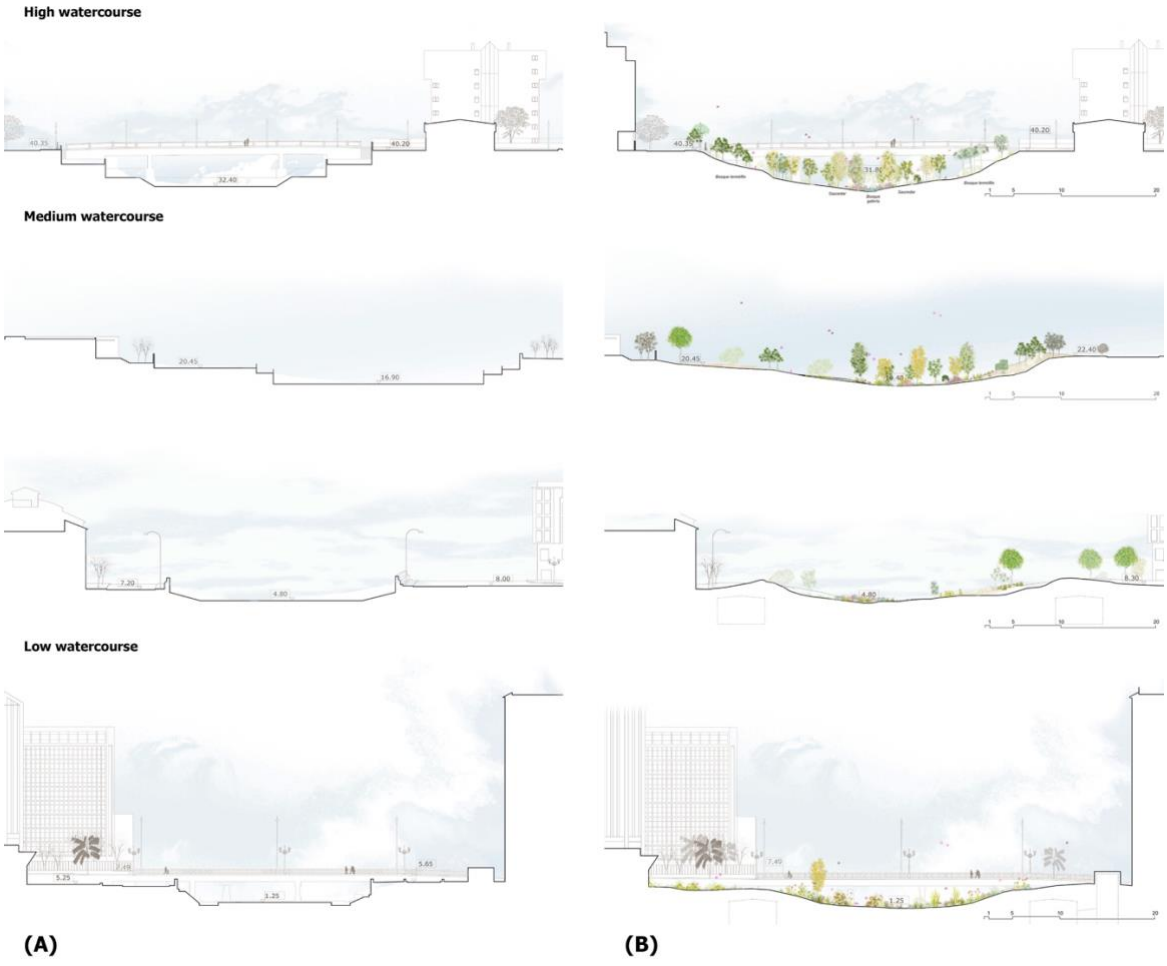

Fig.4 (A) Current state of the Guadalmedina river and (B) Proposal for a biological corridor of the Guadalmedina river

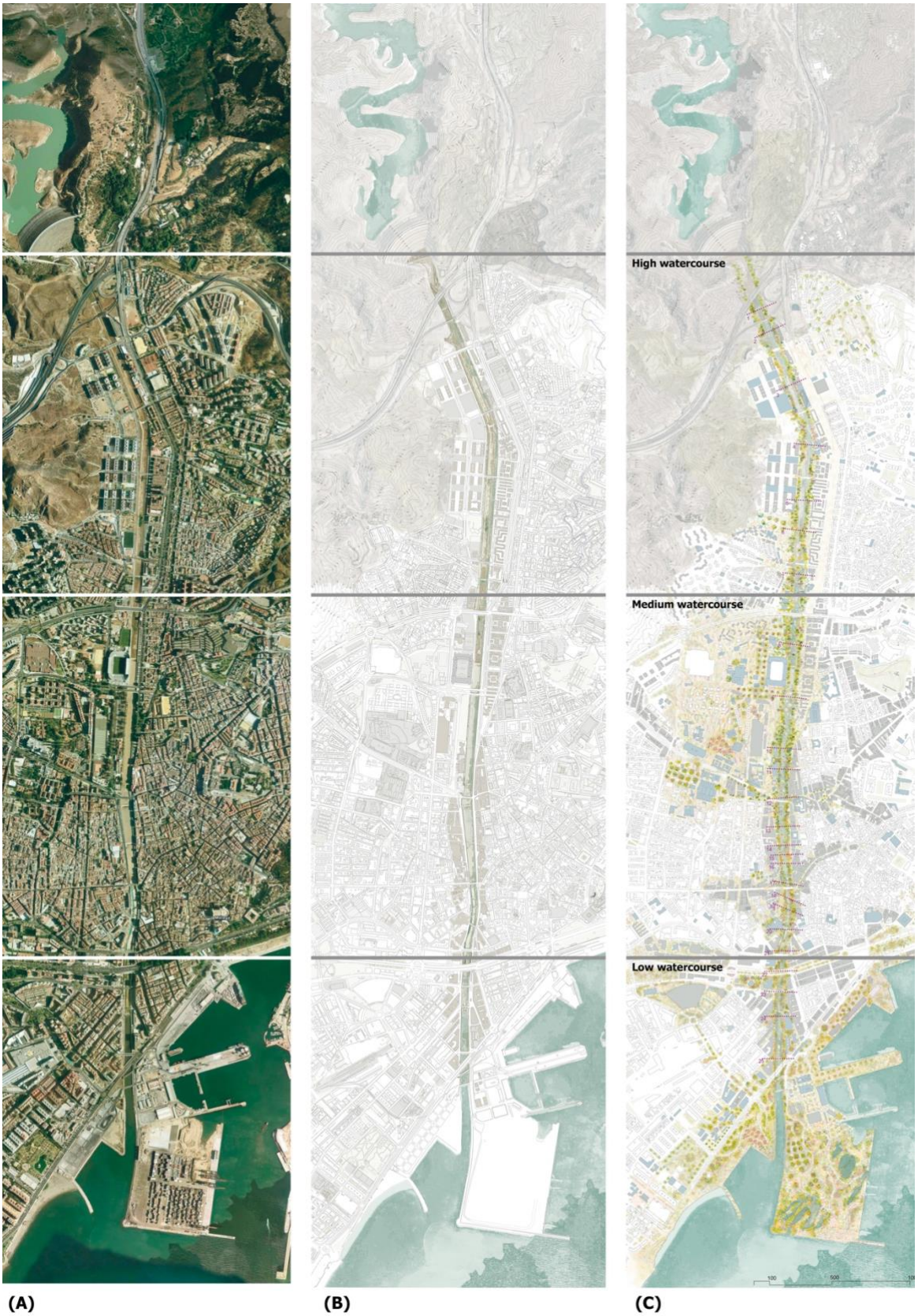

Fig.5 (A) Orthophotography of the urban area, (B) Current state and (C) Proposal for a biological corridor of the Guadalmedina river

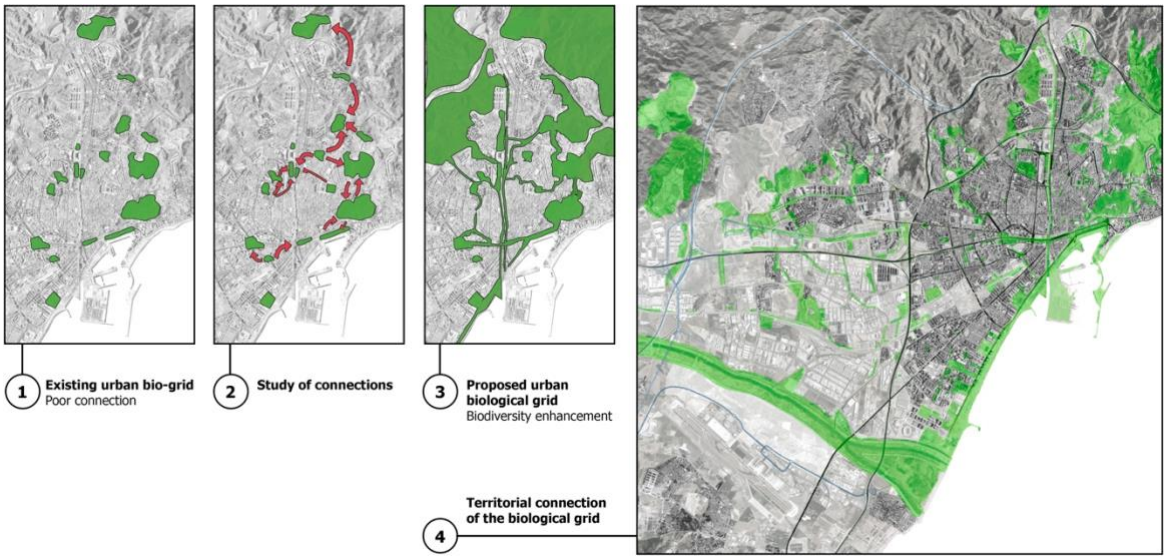

Fig.6 Guadalmedina river into the green infrastructure of the city as a grid of biodiversity

5. Assessment and identification of actions in the framework of a holistic ecosystem approach

Following the analysis of the restoration proposal for the Guadalmedina River, a series of results and actions have been identified in response to the detected issues, aligned with ecosystem-based strategies (Tab.5). The adequacy of these actions is evaluated and discussed within the framework of a comprehensive ecosystem approach and in relation to the previously identified restoration strategies:

Issues	Strategies	Actions
Alteration of the hydrological flow regime – Deforestation of the catchment – Changes in land use in the basin – Erosion and increase in slope gradients in the basin – Alteration of sediment dragging – Deviation of the natural course – Construction of dams, dykes and weirs – Longitudinal, transversal and vertical disconnection of the watercourse	**Restoration of the natural hydrological regime** – Reforestation of the catchment – Land use management – Retain soil on watershed slopes – Reconnection of rivers with their floodplains – Removal of dams and dykes and weirs – Allow minimum ecological flow – Restore hydrological connectivity (transverse, longitudinal and vertical) – Improve water retention and filtration	– Planting of 7,000 hectares – Creation of artificial wetlands
Geomorphological modification – Alteration of topography in floodplains Erosion of banks – Channelisation and artificial channelling of the river channel – Channel diversion – Urbanisation of the flood bed – Linear riverbank infrastructures – Waterproofing of soil – Decrease in surface water retention and infiltration – Increase in surface runoff (flow) – Construction of harbour at the mouth of the river – Existence of underground conduits for installations	**Geomorphological rehabilitation** – Giving more space to the river – Unclogging and restoration of natural watercourses – Stabilisation of riverbanks using bioengineering techniques – Creation of meanders and other natural structures to improve river dynamics – Dismantling of linear infrastructures on the riverbanks – Permeabilise soil – Increasing surface water retention and infiltration – Reducing surface run-off (flow)	– Creation of flood plains for river flooding – Increasing space in the river, creation of sediment islands, removal of old concrete defences
Loss of biodiversity – Destruction and fracturing of natural habitats – Introduction of alien and/or invasive animal and plant species – Fragmentation and degradation of aquatic and terrestrial ecosystems – Loss of ecological connectivity	**Revegetation and habitat restoration (increasing biodiversity)** – Planting of native vegetation on the banks of the river and its tributaries – Increase ecological connectivity to facilitate the movement of matter and species	– Creation of ecological corridors – Connection to other ecological spaces and corridors in the city (Green Infrastructure)

	– Improve the longitudinal continuity of flows, sediments and biota – Improve environmental conditions for the development of fauna – Control and eradication programmes for exotic and/or invasive species	
Water management problems – Overexploitation of water resources – Conflicts over water use between different sectors (industrial, agricultural, domestic)	**Integrated water management** – Development of water resources management plans at basin level – Promotion of efficient water use practices in agricultural, industrial and domestic sectors – Promotion of aquifer recharge and groundwater conservation	
Flooding – Reduction of natural flood areas – Increased flood risk due to urbanisation and soil sealing (surface flow)	**Reduction of flood risk** – Contribute to the lamination of river floods – Improving urban drainage and green infrastructure – Implementing early warning systems and emergency plans – Restore missing lagoon habitats – Protection of existing natural flood zones	– Creation of flood parks and temporary retention areas – Soil permeabilisation – Implementing early warning systems and emergency plans
Pollution – Discharge of sewage without adequate treatment – Discharge of industrial waste – Pollution from rubbish and solid waste	**Improvement of water quality** – Construction of wastewater treatment plants – Implementation of industrial waste management systems – River clean-up and rubbish collection programmes	– Construction of wastewater treatment plants – Riparian vegetation acts as a natural filter
Landscape and recreational degradation – Loss of green spaces and recreational areas – Disconnection of the river from the urban and social life of the inhabitants – Pedestrian disconnection – Citizen ignorance of ecosystem functioning	**Encouraging recreational and educational use** – Enhance scenic and aesthetic value – Increasing the recreational value of the river – Promote sustainable mobility (increase pedestrian and cycling connections) – Re-use and coordinate facilities around the river – Encourage citizen access – Promote education, awareness-raising and environmental education and dissemination	– Development of green spaces and riverside parks|Creation of longitudinal and transverse pedestrian and cycle paths – Creation of recreational areas along the river – Educational and awareness-raising programmes on the importance of urban rivers
Lack of comprehensiveness – Renaturalisation projects with rigid and non-adaptive proposals	**Integrality and territorial function** – Recovering the territorial function of the river – Integration into the green infrastructure of the city	
Lack of collaboration and difficulty in management – Lack of coordination between bodies that administer the public water domain – Non coincidence of basin boundaries with administrative boundaries (lack of coordination between municipal or provincial administrations) – Renaturalisation projects decided hierarchically	**Collaboration and Co-governance** – Generate systemic processes (integrated and synergetic set of diverse actions and techniques (legal, administrative, financial, structural) – Integrate citizens in the design, implementation and management processes of restoration	

Tab.5 Issues of urban rivers and main strategies and actions for renaturation

The proposal is based on an exhaustive analysis and diagnosis conducted over an extended period. Both the analysis and diagnosis phase and the creation of proposals have been carried out in an interdisciplinary way. An open, flexible, and comprehensive process is proposed, aimed at achieving the maximum possible improvement in the ecosystem functioning of the entire river basin (enhancements in geomorphological, physicochemical, and biological functional characteristics). This can be estimated in Tab.6, showing how the baseline situation can be improved by the project.

Indicators	Variables	Current Status	After project
Safety	Flood risk	● ● ● ○ ○	● ○ ○ ○ ○
	Sediment entrainment	● ○ ○ ○ ○	● ○ ○ ○ ○
	Loss of vegetation cover	● ○ ○ ○ ○	● ○ ○ ○ ○
	Loss of biodiversity	● ● ● ● ○	○ ○ ○ ○ ○
Environmental	Biodiversity	● ○ ○ ○ ○	● ● ● ● ○
	Ecosystem status	● ○ ○ ○ ○	● ● ● ● ○
	Biological connectivity	● ○ ○ ○ ○	● ● ● ● ○
	Adequacy of cyclical water status	○ ○ ○ ○ ○	● ● ● ● ○
	Water quality	● ○ ○ ○ ○	● ● ● ○ ○
	Air quality	● ● ○ ○ ○	● ● ● ○ ○
	CO_2 absorption capacity	● ○ ○ ○ ○	● ● ● ○ ○
	CO_2 emission per person/transport	● ● ● ● ○	● ● ○ ○ ○
	Soil permeability	○ ○ ○ ○ ○	● ● ● ● ○
	M^2 of green space per inhabitant	6.4 m^2	15 m^2
	Access to green space of 1000 m^2 within 200 m	10%	16%
	Access of 500 m^2 green space to less than 750 m	20%	30%
	Access to green space of 1 ha within 2 km	35%	50%
	Access to 10 ha green space within 4 km	12%	58%
Functional	Longitudinal connectivity	● ● ○ ○ ○	● ● ● ● ●
	Transversal connectivity	● ● ○ ○ ○	● ● ● ● ○
	Local, metropolitan and global interconnectedness	● ● ● ○ ○	● ● ● ● ○
	Habitability of urban space	○ ○ ○ ○ ○	● ● ● ● ○
	Accessibility by public transport	● ○ ○ ○ ○	● ● ● ● ○
	Pedestrian or non-motorised transport accessibility	● ○ ○ ○ ○	● ● ● ● ●
	Degree of urban complexity	● ● ○ ○ ○	● ● ● ● ○
	Diversity of activities	● ○ ○ ○ ○	● ● ● ● ○
Socio-economic	Agricultural land use	○ ○ ○ ○ ○	● ● ○ ○ ○
	Balance of land uses	○ ○ ○ ○ ○	● ● ○ ○ ○
	Use of renewable energy	● ○ ○ ○ ○	● ● ● ○ ○
	Energy distribution	● ○ ○ ○ ○	● ● ● ● ○
	Access to basic facilities and services	● ● ○ ○ ○	● ● ● ● ○
	Economic cost of maintaining urban space	● ○ ○ ○ ○	● ○ ○ ○ ○
Identity	Landscape	○ ○ ○ ○ ○	● ● ● ● ●
	Ethnological	● ○ ○ ○ ○	● ● ● ○ ○
	Anthropological	● ○ ○ ○ ○	● ● ● ● ○
	Heritage/Historical	● ○ ○ ○ ○	● ● ● ● ○
Citizenship	Transparency	● ○ ○ ○ ○	● ● ● ● ●
	Dissemination	● ○ ○ ○ ○	● ● ● ○ ○
	Participation	○ ○ ○ ○ ○	● ● ● ● ○
	Collaborative creation	○ ○ ○ ○ ○	● ● ● ● ○
Legal framework	Legal	● ○ ○ ○ ○	● ● ● ● ●
	Informal	● ○ ○ ○ ○	● ● ● ○ ○
	Common	● ○ ○ ○ ○	● ● ● ● ○

Tab.6 Estimation of the indicators before and after the Guadalmedina project

The proposed strategies are not formalized; instead, actions can be formalized through collective consensus with the community, associated with a pedagogical process over time, according to needs, demands, and economic resources. The proposed actions address the problems identified in all sections of the basin, are

nature-based actions (NbS), and comprehensively tackle the strategies studied in section 5, which are proposed as necessary for the renaturalization of rivers. This approach contrasts with other proposals studied for other Mediterranean Spanish rivers, which only partially address these strategies.

- At the river basin level, the treatment of the vegetation cover is generally aimed at proposing riparian vegetation and forests and/or improving their conservation status, reducing fragmentation, decreasing the impact of invasive plants, and promoting the diversity of native species. This approach is particularly aligned with the requirements of the Habitat Directive and the ENIVCRE (Ministerio para la Transición Ecológica y el Reto Demográfico, 2023). The introduction of riparian vegetation, the restoration of meanders and wetlands, and the creation of proposed controlled flood areas contribute to mitigating flood risks and promoting biodiversity by providing habitats for various species that depend on this ecosystem (Gómez-Baggethun & Barton, 2013; Tockner et al., 2010).
- The opening of the dam achieves one of the main objectives of river restoration, which is to obtain a watercourse with improved environmental characteristics compared to the current situation of the river, which currently has a zero flow for most of the year, without further aggravating its current state of degradation and reversing the degraded conditions as much as possible (Pires Veról et al., 2019). This is consistent with the requirements for assessing ecological status identified by national water regulations (Water Law) and the European Water Framework Directive 2000/60/EC (WFD). According to an integrated analysis of the initial changes that occurred in the Manzanares River (Madrid) after the opening of the gates and the recovery of flow (Díaz-Redondo et al., 2018), achieving an ecological flow would improve the main components that determine habitat quality and heterogeneity (physicochemical, hydromorphological, and biological elements). According to the study, the river's natural processes would produce changes in sediment transport and water depth-velocity, which would, in turn, facilitate habitat improvement and the recovery of characteristic plant and animal biota of this type of Mediterranean river. In this way, "process-based" river restoration strategies are used, which help the river evolve through more cost-effective interventions focused on recovering self-forming dynamics, such as the opening of the dam (Díaz-Redondo et al., 2018). These strategies are considered appropriate as they have been successfully implemented in other studied projects. On the other hand, the opening of the dam would prevent an existing risk of sedimentation and overflow, as it is located at the head of the city and poses a significant danger.
- Channel Modification. The proposal aims to provide more space to the altered river channel, which is fundamentally required for the geomorphological restoration of a river. The proposed heterogeneity for the channel increases the diversity of hydraulic conditions and physical habitats compared to a single-thread channel (Belletti et al., 2015). Greater geomorphological diversity creates more variability in water depths and velocities, which in turn provide suitable habitats for a wider range of fish ages, sizes, and species (Ahilan et al., 2016; Booker, 2002). By giving space to the river and facilitating physical processes of flooding, sediment transport, erosion, deposition, and channel change, complex fluvial forms would be created and maintained, which, according to Kondolf (2011), is the most effective sustainable approach for restoring the river's ecological value and allowing it to "heal itself." At the hydraulic level, incorporating vegetation increases the Manning coefficient and stabilizes the slopes in the channel, ensuring that water speed, in case of a dam release or significant rain, can be dissipated, guaranteeing drainage and safety. Although the actions in the urban section also aim to generate more anthropogenic uses (recreational, hydraulic, aesthetic, etc.), a global approach is proposed, respecting the river's spatial and temporal dynamics and considering interactions between the urban section and its river basin. This comprehensive approach applies from the initial diagnosis of the pressures affecting the river to the specific actions to be implemented.

- Regarding the species for the proposed revegetations, both at the basin level and in the urban section, they are based on the planting of native trees and shrubs, as well as the system's own resilience, considering that natural fluvial processes will allow the recovery of natural vegetation around the channel after interventions. They are designed to achieve the territory's "climax" state, i.e., towards its maximum autonomy and biodiversity with minimal energy expenditure from all its components.
- With the proposal to integrate the river as an ecological corridor within the green and blue infrastructure network of the city of Malaga, the river's connecting function with other associated ecosystems is utilized, which is necessary to implement an ecological network at the city level that improves its ecosystem functioning and increases urban resilience. Additionally, linking to other parks or green areas in the city provides recreational and aesthetic value to the population, enhancing the urban landscape and increasing the inhabitants' well-being (Tunstall et al., 2000). The inclusion of trails and recreational areas along the river, and the promotion of sustainable uses, encourages the connection of citizens with the river and its surroundings, improving urban quality of life, increasing resilience to climate change, and promoting environmental education.
- From an economic perspective, it has been found that the renaturalization of the basin and the channel is much more economical than other interventions, being more beneficial in social and environmental terms for the city and the territory.

6. Discussion and conclusions

This work explores the role of Mediterranean urban rivers as ecological corridors integrated into the green and blue infrastructure of cities. Through a theoretical-practical approach, it addresses the most relevant issues in river channel restoration, as well as the various strategies necessary to carry out an adequate restoration within the framework of a comprehensive ecosystem approach.

Through a literature review and the analysis of various ecological restoration projects in Spanish river environments, this work aims to systematize the common problems, strategies, and actions implemented in urban rivers. This approach seeks to provide context and understand the key interventions in river restoration projects to serve as a reference for future actions in Mediterranean river channels.

Faced with the challenge of understanding Mediterranean urban rivers as complex systems that require a systemic and multidimensional approach, Foundation Rizoma's proposal for the restoration of the Guadalmedina river in Malaga is taken as a case study, notable for its systemic and integral approach. as it takes the opportunity to propose restoration not only as an ecological element, but also as an integral infrastructure that benefits both the natural environment and the urban fabric. From a more practical perspective, the Fundación Rizoma's proposal for the restoration of the Guadalmedina river in Malaga is taken as a case study.

By analyzing the problems and proposed actions, this project presents itself as a suitable example responding to the new requirements of national and European agendas and emerging sensitivities. The proposal for the river functioning as a fluvial corridor could guarantee medium- and long-term "socio-ecosystem services" for the entire city in terms of ecological stability, reduced hydrological risk, landscape beauty, recreational potential, economic sustainability, and conservation of the river's scientific, hydraulic, and cultural heritage. The operational challenges described in the challenges, such as fragmented catchment management and urban constraints, are addressed in the proposal for the Guadalmedina river by proposing an ecosystem approach, emphasising the need for comprehensive river restoration strategies that address multifaceted problems, from administrative fragmentation to urban pressures:

- An overall planning framework that integrates natural river dynamics with sustainable urban development, connecting green and blue areas to build climate resilience;

- An integrated river planning and management model that includes multiple variables (ecology, risks and usability) and involves multi-stakeholder collaboration, aligning with the concept of a 'river contract';
- A sustainable economic process based on ecosystem strategies that prioritise adaptation to climate change over rigid and costly infrastructures.

The restoration of the Guadalmedina River is presented as an opportunity to implement natural strategies that not only mitigate the negative effects of climate change, but also offer long-term socio-ecological benefits. In this sense, the work reflects how rivers can evolve from being considered urban 'scars' to functioning as dynamic 'arteries' that connect fragmented ecosystems, a metaphor directly related to the idea of rivers as ecological corridors and part of the green and blue infrastructure.

From the study of this specific proposal, a series of general conclusions can be drawn that can be transferable to other case studies. Thus it is proposed:

- A general urban and territorial planning framework that establishes plans compatible with the natural dynamics of existing rivers and is respectful of river spaces as environmental and landscape elements of cities with maximum value and conservation interest (Ministerio para la Transición Ecológica y el Reto Demográfico, 2023). This would also help define new land management strategies that incorporate traditional urban design principles as well as reintegrate stormwater into the design of public spaces—relating blue and green surfaces—and consider them an asset and a city resource rather than a threat (Mirsafa, 2017). This would increase effectiveness in reducing disaster risk in planning practice and achieve the sustainability of local water resources and the resilience of the urban environment (Barbarossa et al., 2021);
- River planning and management models that integrate multiple variables (ecology, risk protection, and usability), relating evaluation systems with planning instruments (Palermo et al., 2021). Effective collaboration through a "river contract" between administrations, institutions, sectoral authorities, local communities, and other stakeholders. Collaborative processes should be carried out, including citizens in the analysis, design, and management of river basins, especially when the river constitutes a landscape-identifying element (Cialdea & Pompei, 2021);
- From an economic perspective, budgeting for long-term processes that start with a comprehensive understanding of the territory and are addressed in phases over time is more in line with ecosystem-based strategies and nature-based actions. Proposals that align with natural processes tend to be more economical than large infrastructure projects and offer greater social and environmental benefits.

In general, river restoration efforts require a greater awareness and understanding of the problems and solutions related to urban rivers and a change of perspective from an anthropocentric to a more ecocentric society. From the outset, the proposal for the Guadalmedina River includes a pedagogical effort and the dissemination of ideas through workshops, activities, visits and tours of the river basin, the publication of a book, etc. The proposal for the Guadalmedina river, however, is of a theoretical nature and has not been carried out. Instead, Malaga City Council has developed a Special Plan for the urban section of the river which proposes to partially cover the riverbed by means of 'square bridges' without incorporating ecological considerations for the river. However, the original proposal remains valid as an alternative and more comprehensive approach to the regeneration of the Guadalmedina River, offering an ecological and sustainable vision for the future of the river.

It can be concluded with Tánago y Jalón (González del Tánago & García Del Jalón, 2007) that a viable outcome of an urban river restoration consists of a more self-sustaining system, which may or may not be similar to the natural state, but that adds environmental value to the river. At the same time, it contributes to flood mitigation and offers alternative uses for society, integrated into the city as a landscape reference element. Further research is needed to deepen the understanding of urban rivers as biological corridors: studies on

functional connectivity, the impact of climate change, and renaturalization or ecological restoration practices that guide future conservation efforts (Gómez-Baggethun & Barton, 2013).

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Image Sources

Fig.1: Location of the Guadalmedina river in Malaga (Spain). Rizoma Foundation.

Fig.2: (A) Current vegetation of the Guadalmedina river basin and (B) Potential vegetation of the Guadalmedina river basin. Rizoma Foundation.

Fig.3: (A) Current land-uses in the Guadalmedina river basin and (B) Climax status of the Guadalmedina river basin. Rizoma Foundation.

Fig.4: (A) Current state of the Guadalmedina river and (B) Proposal for a biological corridor of the Guadalmedina river. Rizoma Foundation.

Fig.5: (A) Orthophotography of the urban area, (B) Current state and (C) Proposal for a biological corridor of the Guadalmedina river. Rizoma Foundation.

Fig.6: Guadalmedina river into the green infrastructure of the city as a grid of biodiversity. Rizoma Foundation.

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Vulnerable Viterbo. Ancient city form and contemporary pressures

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Abstract
In Italy the problem of climate change is a question of study that is unfortunately quite recent, more or less since 2015 we have started to understand that this problem exists but it often remains only in administrative theory. The context of the study is emblematic because it is defined by the city of Viterbo in which the system of urban planning rules belongs to a vision, to an idea of the city developed between the 1950s and 1960s and culminated in the approval of the PRG "Smargiassi-Salcini" of 1956 which then merged into the General Variation of 1979, the last unitary instrument of control of the city. Since the 1980s, the city has escaped any holistic vision, avoided the urban planning approach and governance, and pursued its own development outside the master plan rules, favoring the partial variants. The National Recovery and Resilience Programme, presented and hoped for by many as a policy to control territorial imbalances, has not succeeded in this undertaking and has actually contributed to widening the gap between what falls within the domains of the urban planning discipline and what is instead delegated to mere urban or even architectural design.

Keywords
Urban form; Planning; City of Viterbo

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1. Introduction - City form versus climate change

Hail is the result of what the ancients called "a complex dance between air, water and ice in the upper spheres of the atmosphere"; it occurs when the warm air present on the ground rises into the atmosphere carrying humidity and meets the cold air; this creates continuous vortices in which the grain is formed which, with each complete turn of ascent and descent, becomes more voluminous and heavy and when the hailstones reach a mass sufficient to overcome the force of gravity, they begin to fall towards the ground. These phenomena, like those of cloudbursts, are now characteristics of the era of climate change when warm and cold air meet more and more easily and suddenly. Technically, a cloudburst occurs when the quantity of water that hits the ground exceeds 30 millimetres per hour (Legambiente, 2017).

"Water has always played a key role in the dynamics of growth and in the development of a territory; the waters have always been at the center of the history of civilizations; the territories furrowed by the great "water infrastructures" were the first to be urbanized by man and marked the first human settlements (Moraci et al., 2020); water has been at the center of the classical mythology of the gods and has been at the center of religious rituals that have exalted its sacred nature linked to its recognized healing abilities. The water space is a place of intense vitality, a space of relationships, of exchange, a connective tissue, a fluid environment in which flows of people, of goods and of knowledge are realized; the water space, the limit between land and water, is a strategic space, often protected, where a strong landscape and environmental value are recognized; but it is also a strategic space for the transformation of the city" (Errigo, 2018a).

A resilient world places the focus on learning, experimentation and the development of local rules, and embraces changes. One approach to resilience is to encourage new developments and innovations (Colucci, 2012). The resilience in urban planning is crucial for sustainable development, resistance to shocks, creation of adaptive systems important for resilience to fluctuations (Meerow et al., 2016) and allows the cities to resist and recover from hazards and security threats (Godschalk, 2003).

In Italy the problem of climate change is a unfortunately quite recent topic of research, more or less since 2015 (IFAD, 2016) but it still often remains only in administrative theory (Errigo, 2018).

The context of the study is emblematic because it is defined by the city of Viterbo in which the system of urban planning rules belongs to a vision, to an idea of the city developed between the 1950s and 1960s and culminated in the approval of the Comunal Urban Plan "Smargiassi-Salcini" of 1956 which then merged into the General General Urban Planning Variant of 1979, the last unitary instrument of control of the city. (AA.VV, 1993); concepts such as climate change and resilience, intimately interconnected, are revealed to be exempt in the urban planning instrumentation of Viterbo and also in many recent urban projects.

Since the 1980s, the city has eluded any holistic vision, avoids the urban planning approach and governance, and pursues its own development (perhaps it would be better to say growth), outside the rules of the master plan, privileging partial variants. The National Recovery and Resilience Plan, NRRP, in Italian: Piano nazionale di ripresa e resilienza, PNRR, presented and hoped for by many as a policy to calm territorial imbalances, has not succeeded in this endeavor, rather it has contributed to widening the gap between what falls within the domains of urban planning and what is instead delegated to the mere urban or even architectural project. The concept of the future city focuses on the optimization of the relationship between technological advancement and challenges of sustainability at the urban scale (Moraci & Fazia, 2013).

Viterbo is a city that has a surface area with a population that does not reach 70 thousand inhabitants with a surface area of 406 kmq characterized by excellent air quality should be easily considered a safe city from a climatic point of view.

It is true that we inherit a city built and modified when this theme was not known but since 2015 the lighthouse has been turned on and a planning attitude should be synchronous, especially in public works, equal to the multitude of signed acts; in 2016 the city joined the Covenant of Mayors by signing the Action Plan for sustainable energy (Città di Viterbo, 2020), as part of the "Experimental program of interventions for

adaptation to climate change in urban areas", promoted by the Ministry of Ecological Transition, funding of approximately 576 thousand euros was also obtained for the implementation of projects functional to mitigate the effects of climate change and we also remember that the current Mayor of Viterbo was in Milan last 5Th of June where he exposed the fight against climate change and pollution, signing the "Nature-Positive Cities" charter. In short, attention seems to be at its maximum but the projects do not align with expectations.
As the EU study "Soil sealing" shows, peak intensities are related to land consumption, for every 1% increase in land consumption the peak intensity (strength and violence) of precipitation increases by 3%. This means that the more the soil is sealed, the more damage is caused to the city. (Pennino et al., 2024).
Thinking from a contemporary perspective, a city that has invested almost 100 million euros with Regional and PNRR funds in the last two years should have developed projects that contribute to making it safer, what we would call contemporary projects. The aim of this article is to demonstrate how traditional urban planning and recent urban design are on a parallel plane with respect to the indications of the PNRR. The city has distinguished itself for urban acupuncture projects rather than for systemic urban logics.
The aim of the paper is to investigate the planning approach of the City of Viterbo and the recent attitude towards the planning, specially the resilience aspect important in contemporary approach to sustainable development.

2. Urban planning and lack of land management

Viterbo area was known even in Etruscan (Scarponi, 2014) and Roman period (Marino, 2014). The City of Viterbo is a medieval city surrounded and protected by mighty walls (Fig.1); the oldest districts of the city are San Pellegrino and Pianoscarano (Bentivoglio, Valtieri, 1982), medieval districts dating back to the year 1000 whose fabrics still retain the same medieval stratification with buildings constructed in peperino stone on tuff rock without foundations whose walls are built from roughly squared stones with a purely static function (Pinzi, 1993). In fact the city shows some of the typical characteristics of Mediterranean towns such as dense irregular urban texture, stratification of heritage and others (Marović et al., 2022). In 1886 the first city station was built (Viterbo Porta Fiorentina) which served the first railway line Viterbo-Attigliano; in 1894 the second city station was built (Viterbo Porta Romana) which was immediately connected to the Porta Fiorentina station and was intended to connect the city to Rome.
The Pizzini Plan of 1886 mainly questioned the urban form and was mainly aimed at restructuring the centre and the projections towards the outside were constituted by the Bagni road, the opening of Porta Murata which connected the centre with the railway station and the demolition of Porta Fiorentina which connected the city with what in the second half of the 19th century had become Prato Giardino.
In 1912 the Caterina Plan was adopted, which aimed to restore the historic center and improve the road system, providing for expansion in neighborhoods tangent to the city walls, using the Via Cassia as a connecting infrastructure. The Cristofori Plan of 1919 was a project for the enhancement of the thermal waters that he saw as a real opportunity for the economic redemption of the city, the Bullicame was to be welded to the city by means of a 2-kilometer avenue that started from the ancient Porta Bove. The avenue, 50 meters wide and perhaps inspired by the linear city of Soria Y Mata, included a double tram track in the center that two tree-lined strips separated from the roadways; there were also wide tree-lined sidewalks and two strips of building land 75 meters deep intended for villas, hotels and entertainment facilities (AA.VV., 1993).
In 1927 Viterbo became the provincial capital and in the following decade, some public works were completed which transformed the image of the city such as the covering of the Urcionio torrent and the first demolitions of the curtain walls in via Rosselli and in the vicinity of Piazza Francesco Crispi (Gimma, 2001).
The covering of the Urcionio, completed in 1935, allowed the construction of a modern axis crossing the center that started from via Fratelli Rosselli, continued on via Marconi (area of the buried ditch) to join with via Filippo Ascenzi and Piazza del Plebiscito and towards the south with a new road that connected Porta Faul and towards

the west with a new avenue that connected Porta Bove. From Porta Bove started an avenue that connected to the spa (Gimma, 2001). The 1936 Plan envisaged 6 expansion districts outside the walls.
In the 1940s, the city of Viterbo still coincided with the ancient city walls within which, with the covering of the Urcionio, a wide crossing road had been created in a North-East/South-West direction and with extensions around the railway hubs and Prato Giardino.
The first urban planning instrument approved in the city was the Reconstruction Plan of 1946 by the architect Antonio Piraino which was drawn up to rebuild the city after the heavy bombings of the Second World War and which however had as its main characteristic the doubling of the land indices in the historic center and as a consequence the complete transformation of the ancient medieval and Renaissance fabrics with the modification of the building typologies. In some cases, building permits were granted in derogation from the plan, also compromising the road system (for example at the mouth of the Cassia Cimina). The Piraino Plan was inspired by the Mainardi Plan because it concentrated the residential neighborhoods in the Cappuccini – Verità – Pila and Viale Trieste areas and the industrial areas on Via Teverina and Via Cassia.
In 1956, the first real urban planning tool was finally approved, the Master Plan drawn up by Eng. Smargiassi and Arch. Salcini, which was the first real tool, after the Cristofori Plan of 1919, that dealt with urban mobility and infrastructure, proposing the creation of rings that surrounded the entire inhabited center, running nine kilometers around it and surrounding the streets that penetrated the fabric of the historic center.
The system of urban planning rules belongs to a vision, to an idea of the city developed between the 1950s and 1960s and culminated in the approval of the Urban Municipal Plan "Smargiassi-Salcini" of 1956, which later merged into the General Urban Planning Variant of 1979, the last unitary instrument of control of the city.

Fig.1 Ancient map of Tarquinio Ligsutri dated 1596

It is a detailed work, everything comes to life from the old center represented by the designers as a pulsating red heart. One of the weak points of the plan was to have left as white areas some agricultural areas to the west and east that were then progressively built, the white areas did not fall within the requirements of the PRG but those of the building regulation of 1928 which allowed a high index of buildability.

Fig.2 Map of Mainardi Plan (1936)

The General Urban Planning Variant of 1979, the last and still valid urban planning instrument of the city, was built with the same logic as the previous Urban Plan because it continued to highlight the problem of the city from an infrastructural point of view, paying particular attention both to the expansion to the south of the city and to the strengthening of the relief of Viale Raniero Capocci with the creation of the semi-ring ring, still highly strategic for the city.

The Urban Plan considered the intervention on the Orte-Viterbo-Civitavecchia axis and the Nuova Cassia to be strategic for the connection with Rome. The SS 675 was also supposed to relieve the flow of traffic crossing the center.

Attention was paid above all to the flows of residential expansions (Cappuccini, Murialdo, Paradiso, Ellera, Pila, Grotticella and Mazzetta) with the creation of a semi-ring that relieved the flow towards Viale Capocci. The sports center was identified to the north on the Teverina road; several expansion districts were identified and for the university the Urban Plan envisaged not a campus but several locations that would occupy abandoned historical volumes (to encourage integration with the city).

The historic center did not find a precise location in the variant project and its redevelopment was deferred to the detailed plans.

The expansion in the 80s involved the neighborhoods of Santa Barbara, Ellera and Carmine and Pilastro for subsidized and agreed public housing and the areas of Murialdo, Barco, Pila, Grotticella, Pietrare and Ellera for private housing.

For services, the Plan identified the neighborhoods of Riello, Palazzina, Teverina, Belluno while for management activities the neighborhoods of via Garbini, Riello and Pietrare. The industrial areas and zones were located to the north, at Poggino and on the Teverina.
The region of Viterbo has experienced significant urbanization since the 1960s even in places with population drops (Romano and Zullo, 2014), which makes it even more challenging to have the most recent plan created before 1980s.

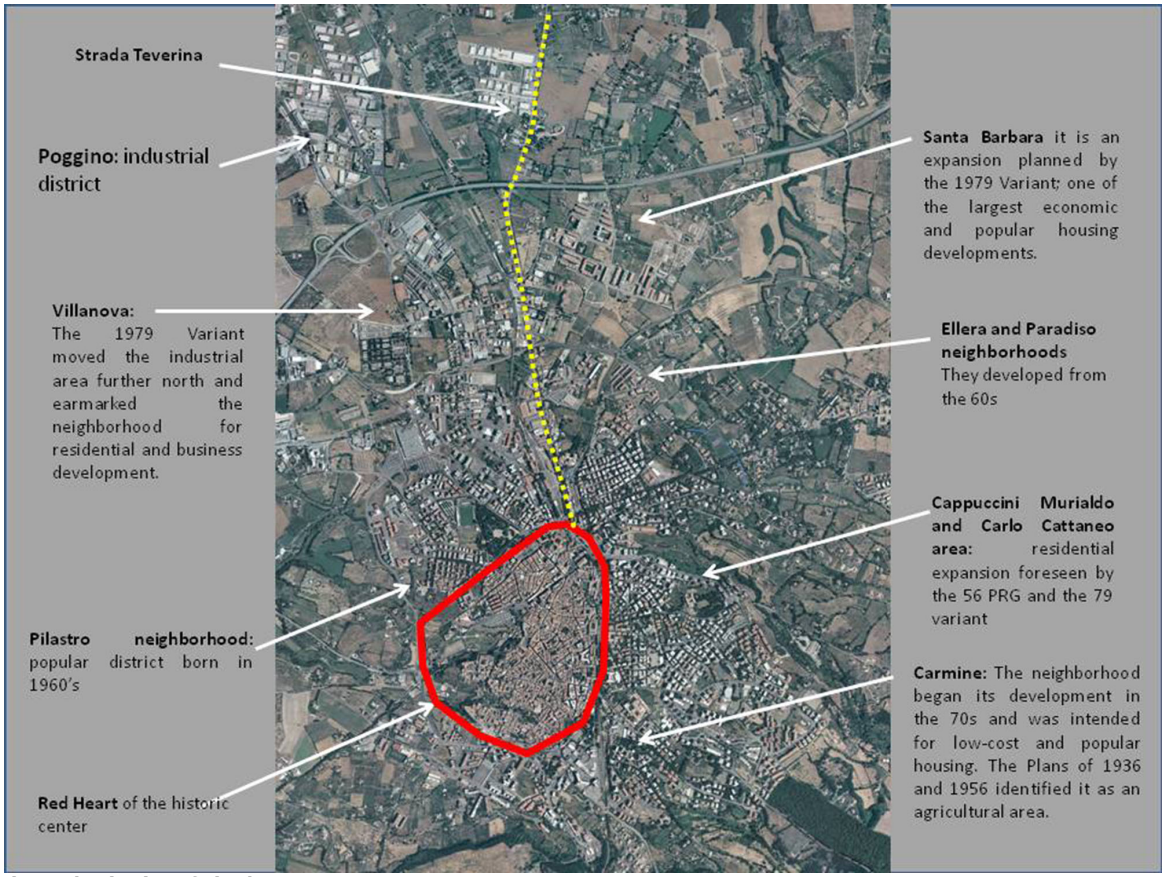

Fig.3 Urbanisation of Viterbo

3. Innovations, projects, urban debate

In recent years, especially in the last two years, the city (Fig.3) has formally become aware of the lack of urban planning or at least the need for its updating; the urban planning tool still in force is the General Variation of 1979 supported, for the historic center, by a 2014 Ornamentation Regulation which however lacks the part relating to the prescriptions on colors. In recent period, the city has been dealing with the drafting of three fairly important urban planning tools: the Recovery Plan for the historic center which will start in 2025; the Architectural Barrier Elimination Plan which is in the start-up phase with the detection of critical issues through questionnaires, and the Sustainable Urban Mobility Plan (Moraci et al., 2018), also in the start-up phase and the detection of problems through questionnaires. The "Regulation on the monetization of urban planning standards and related parking" was also approved in 2024 (Comune di Viterbo, 2023) with which it is possible, when building or renovating a building by increasing its volume or changing its intended use, to no longer cede the surfaces for the creation of service areas, but on the contrary to pay the municipality an alternative amount to the direct cession of the same areas without creating standards (Karrer et al., 2020) or relevant parking lots. Monetization is defined by some regional urban planning laws as a residual option to be applied only where it is not possible to achieve the mandatory urban planning standards; in many rulings of the Council

of State it is established that the areas created with the monetization of the standards must be functional to the urban planning load induced by the new building interventions.

Fig.4 The ancient city surrounded by green surface and new districts

Article 3 of the regulation allows monetization for "building interventions to be implemented in the homogeneous territorial zones of Type A and B, pursuant to Ministerial Decree 1444/68 and subsequent amendments, as well as in those of Type C implemented and subject to the issuing of the direct or agreed building permit pursuant to art. 28 bis of Presidential Decree no. 380/01 and subsequent amendments."; it is clear that this is a regulation that can directly affect the urban form and the conformation of the building sectors given that the C zone, according to the Viterbo Master Plan, "includes the parts of the territory intended for new settlement complexes that are still unbuilt or in which the pre-existing construction does not reach the surface area and density limits established for the B zone"; in Viterbo the C zone has 18 sub-zones, therefore 18 different types of areas of the non-historical city. The monetization of the standards in areas like C zones in a city favors the creation of an expansion without services (for example wtihout the parking lots) while in the suburbs the parking quota should almost help the mobility of the historic center and in any case raise the urban standard considering that Viterbo is one of the cities with the highest national rate of motorization (74 cars for every 100 inhabitants)[1] (Legambiente, 2020).

[1] In Italy there are have 62 cars per 100 inhabitants; Italians are considered the "major car consumers" in Europe; travel by car represents around 80% of urban mobility in Italy: more than double the European average. In Stockholm, the use of the car as a means of private transport represents only 25% of urban mobility. In London, 85% of commuters travel on public transport, in Milan only 45%. 50% of trips that occur in urban areas are less than 5 km, 30% are less than 3 km; the distances that can mostly be easily covered by bicycle or, in some cases, on foot. According to a survey by the Italian Automobile Club, out of 105 Italian provincial capitals, the city of Viterbo is characterized by one of the highest Italian motorization rates with 77 cars per 100 inhabitants, on par with cities such as L'Aquila and Potenza and only surpassed by Catania and Vibo Valentia (78 cars per 100 inhabitants), Isernia (79 cars/100 inhabitants) and Frosinone which holds the national record with 80 cars per 100 inhabitants. Virtuous cities in this context appear to be some metropolitan cities such as Bologna (53 cars/100 inhabitants), Florence (56 cars/100 inhabitants), Genoa (48 cars/100 inhabitants) and Milan which has as many as 49 cars per 100 inhabitants as evidence of the important strategies on public urban mobility carried out in recent decades. Looking at the cities with which Viterbo is related by system hierarchy or by similarity in size, we can see that Terni and Siena have 67 cars per 100 inhabitants, Perugia 75 per 100 and Rieti 74 per 100, all lower numbers, some not by much , to the reality of Viterbo.

The Regulation on the monetization of standards and appurtenant parking is certainly a useful tool, it probably should have been approved after the drafting of the recovery plan for the historic center and should probably have been almost "armoured" within the historic areas (A and B of the Plan). The expansion areas should certainly have been excluded except, perhaps, for small interventions on existing buildings with a small variation in the urban planning load. The Regulation is inextricably linked to the idea of the city; Viterbo cannot afford to increase the urban planning load to the detriment of services such as parking and greenery. The urban form in the era of climate change could suffer heavy repercussions considering that the building filter zones, the resilient buffer zones, are the free surfaces not waterproofed by the urban planning standards. Another consideration must be made on the transformations underway with the projects approved with resources from the National Recovery and Resilience Plan; the Municipality of Viterbo in the last two years has shown a certain vitality in participating in calls for tenders and in the use of PNRR resources; consulting the website openpnrr.it it appears that in Viterbo there are 45 active projects that can be implemented with PNRR resources, ranging from the renovation of public buildings, to the redevelopment of infrastructural itineraries, to the strengthening of alternative mobility tools to the car (Pellicelli et al., 2022).
The interventions, some of which have already been announced, will affect different parts of the city in every sector: construction, sports, environment, greenery, sustainable mobility, historic center.
As for public works, the expected amount amounts to half of the overall package, over 13 million are instead destined for school buildings, more than 12 for the medieval heart of Viterbo, 7 for sports facilities, 3 for greenery and over 15 for sustainable mobility. The main interventions are divided into three main areas, which are urban regeneration, securing the territory and strengthening urban mobility; important interventions, for a value of approximately eleven million euros, are also aimed at the recovery of school buildings, which, especially those in the historic center, are characterized by structures built in the 50s. Among the more widespread interventions that affect a large surface area we can mention the creation of an ecological walk along the civic walls (resources mobilized 3 million and 100 thousand euros), which however, in many sections, reveals points of conflict both with mobility, with the cultural heritage and above all with the ecology of the project that includes a belt of impermeable sidewalk along the civic walls even if interspersed with the planting of 88 new trees and some permeable surfaces of some "pocket parks" such as for example in the part facing the Chamber of Commerce. None of these projects is particularly attentive to the introduction of concepts such as urban resilience, the fight against pollution, the fight against the increase in heat islands or the reduction of surface run-off.

4. Conclusions

The contemporary design of public space is a complex topic to deal with, especially where the space is monumental, stratified, strongly identifiable and full of history. (Ricci et al., 2023).
For a good architect, the past is a palimpsest. It is not a discussion of beauty, aesthetics, or what is liked; a project is always the synthesis of a complexity of infinite factors that a good architect must weigh and select and try to offer a shared technical solution that combines history, protection and contemporary needs; this is the real challenge of the project, and here only the best succeed. We can refer to history as long as we have documentary evidence, testimonies such as photos or drawings that may have handed down information to us. However, we cannot know whether before that evidence there may not have been a different conformation of the public space, or of the facade of a building. It is a fragile and risky terrain on which we must proceed with caution. Today in public space projects, protection is the first objective to pursue, especially in precious cities like Viterbo, but a second element, no less important, is the well-being of public space, that is, making that space usable and enjoyed by the population and here we cannot design as we did a hundred years ago because our cities have changed (Fig.3), mainly by virtue of two factors: awareness of fragility and disabilities

and climate change. By virtue of these two factors, a contemporary architect designs a public space with a different awareness, making it accessible and making it less of a heat island (Isola et al., 2024).
The PNRR is making available to cities (including Viterbo) an unprecedented amount of economic resources that could be used largely for actions and projects that allow us to innovate the shape of our cities by acting on the resolution of the most critical problems that are normally safety from environmental risks and urban accessibility. We could also work on a renewal and updating of the urban control tools of the territory, producing clear and innovative studies and prescriptions perhaps inspired by successful national projects and strategies such as the Resilience Strategy of Milan, the projects Resilient Padua, Resilient Mantua, the Climate Change Adaptation Strategy of Reggio Emilia, the Waterproof cities of Rotterdam and Barcelona, the Rotterdam Climate Adaptation Strategy (City of Rotterdam, 2010), the Room for the River programme in the Netherlands, the Water Sensitive Zomerhof, the Watersquares and the Green Roofs programme in Rotterdam, the public space projects in Ghent, Belgium (Ghettingplein), the Yongsan National Urban Park Master Plan in Seoul, the Highline in New York or the projects by De Urbanisten and MVRDV in Rotterdam.
Interventions that, if combined with other projects fundable with other regional and ministerial calls, could really change and transform the urban face of the city of Viterbo, assuming that the city has never managed a wealth of resources like this.

Fig.5 The cloudburst of August 29th, 2024

However, what emerges loudly and clearly even to non-experts is that the interventions planned and designed in recent years are not part of a system logic, a strategy and an urban vision that corresponds to a clear idea of the city. They are all interventions related to the scale of the urban project, in many cases even of the architectural and building project, which are separated from rules and tools for planning and governing the city such as those appropriate to an urban plan and a multi-year program and, as told in the previous chapter, the projects are not particularly attentive to the introduction of concepts such as urban resilience, the fight against pollution, the fight against the increase in heat islands or the reduction of surface run-off and there is low attention also to establish a set of rules able to innovate urban planning framework.
Viterbo has a profound technical contradiction; on the one hand, it is designed with modern and contemporary resources using the scale of the building project and in very few cases urban; on the other hand it still designed

and planed with an old frame of reference, the last plan of 1956, the general variant of 1979 and with a myriad of partial variants approved in recent decades that have distorted any idea of the city that has been elaborated and has emerged from the technical salons developed between the 60s and 70s.

This is even more interesting because during the years, there had been different initiatives to update the planning framework and increased attention to contemporary topics.

In 2013 the City of Viterbo announced the willingness to create the strategic plan based on the, at that moment, cutting-edge premisses of resilience, introducing the concepts of regenerative city, integration of cultural and natural capital, community engagement and trust, sustainable development goals, Historic urban Landscape, circular economy and creation of strategies (Girard et al., 2014). In the similar vein, (Romano and Zullo, 2014) indicate the general issues with the growth in central Italy, shared by City of Viterbo such as: transport diseconomies, energy waste, reduced agricultural land, ecological challenges and the need for considering more population needs and sustainable development, particularly reconversion of abandoned urban areas, creation of observatories and structured communication.

Other research on resilience highlights the aspects such as accessibility (Errigo, 2022), or propose the requalification of historic centre based on the morphology and sustainability (Maretto et al., 2020).Urban planning as a science and above all a technique of governing the city and the territory has been absent in Viterbo for some decades, we can perhaps represent the last phase of the urban planning debate with the image of the red heart, representing the historic center in the distant Mainardi Plan of 1956. An ancient urban form that on the one hand should be preserved as an immense cultural heritage but on the other, at least in the spaces outside the walls, should be reviewed and redesigned with a contemporary perspective to make the city less fragile and safer and more resilient. Seeing today urban and building projects protected by a weak or absent relationship with urban planning rules, because these planning rules are too dated today, turns out to be a big problem to pay attention to and intervene on; the city of Viterbo needs to exit the phase of interpretation and regulatory updating and equip itself with modern and innovative tools that can define rules and times for a new urban season, characterized by protection, climate adaptation and the enhancement of the identity of the city. The new phase that is starting, with the drafting of three important urban planning tools including the recovery plan of the historic center, could be the ideal time to implement the innovation of the government of the municipal territory.

Attributions

Paragraphs 1 and 3 were written by M. F. Errigo; paragraph 2 and 4 was written by M.F. Errigo and I. Mrak.

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Fig.1 Ancient map of Tarquinio Ligustri dated 1596, Bibl. Ap. Vat. Geogr. I, 318

Fig.2 Map of Mainardi Plan (1936) Retrieved from AA.VV. (1993). *Viterbo – Politica, economia, cultura e sport 1945-1992*, DEUI Editore

Fig.3 Urbanisation of Viterbo, image processed by the Author

Fig.4 The ancient city surrounded by green surface and new districts, image processed by the Author

Fig.5 The Cloudburst of August 29th, 2024. Retrieved from https://etrurianews.it/2024/08/27/viterbo-pioggia-vento-e-grandine-allagano-la-citta-e-fanno-oscillare-la-macchina-di-santa-rosa-video/

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The regeneration of former military sites in the context of ecological transition. The case of Cagliari, Sardinia (Italy)

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Abstract

The environmental and ecological dimensions are pivotal in territorial governance, which seeks to mitigate human impact on ecosystems, promote sustainable land use, and strengthen green infrastructure and territorial capital. These goals are embedded within urban and land regeneration policies, which encompass strategies for the redevelopment, enhancement, and reuse of existing settlements. Within this framework, the regeneration of former military sites holds significant importance, emphasizing the repurposing of green spaces to augment the ecological potential of soils through the development of green infrastructure. This approach aims to connect green and natural areas, thereby improving ecological resilience, biodiversity, and the quality of the urban environment. In Sardinia, particularly in Cagliari, a considerable number of unused or decommissioned military facilities have arisen from decreased national defense requirements, with some being transferred to local authorities. The military presence in regions of high environmental and landscape value has had a dual effect: it has contributed to irreversible landscape alterations and environmental pollution, while simultaneously preserving natural resources from urban development. This paper examines the potential role of these assets in urban regeneration strategies, with a focus on ecological networks, territorial rebalancing, and the reconnection of urban fabric, thereby enhancing historical, architectural, and environmental heritage.

Keywords

Military sites; Ecological transition; Urban regeneration

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1. Introduction

The urban regeneration policies are aimed at limiting the anthropic pressure on the environment and land resources, promoting the redevelopment and reuse of existing urban areas to protect the soil and its important ecosystem functions (Pileri, 2023). The European Soil Strategy 2030 (ESS), adopted in 2021, sets out a "hierarchy of soil use", giving priority to avoiding land use and sealing, and to promoting the reuse of already compromised and sealed land (EC, 2021). In Italy, the new National Biodiversity Strategy 2030, adopted in 2023 by the Ministry of the Environment and Energy Security in line with the ESS, aims to address the problem of biodiversity loss and the progressive weakening of ecosystems, with the perspective of restoring and making resilient and adequately protected all global ecosystems by 2050. The strategy promotes processes of renaturalisation of degraded land, also in urban and peri-urban areas, with the aim of reducing hydrogeological risks and enhancing environmental resilience (Munafò, 2023). One of the main objectives of the strategy is to counteract the degradation of urban and peri-urban green ecosystems by promoting the use of Nature Based Solutions (NBS) that allow zero net soil consumption, including through the redevelopment and restoration of contaminated and sealed sites. Nature-based solutions (NBS) are central to the ecological transition and internationally recognised as essential for addressing climate and biodiversity challenges (Kabisch et al., 2016). In the past two decades, concepts such as Nature-Based Solutions (NBS) and Green and Blue Infrastructure (GBI) have emerged to facilitate the integrated planning of green spaces (Andersson et al., 2019; Dushkova & Haase, 2020). Promoting their extensive adoption is crucial, particularly with the backing of the EU Green Deal and associated initiatives. However, climate change, land use, environmental degradation and pollution continue to cause systemic damage to biodiversity and ecosystem services, with land use change being the main driver of impacts on terrestrial and aquatic ecosystems (Pultrone, 2024).

The incorporation of Green Blue Infrastructure (GBI) into urban planning can facilitate the advancement of sustainable urban development, enabling the extensive proliferation of urban green spaces through the establishment of interconnected Urban Green Networks that are in harmony with natural ecosystems (Tulisi, 2017). Green infrastructure (GI) offers significant advantages, including the mitigation of climate change, the enhancement of air and water quality, the conservation of biodiversity and the provision of recreational spaces for collective well-being (Beauchamp, Adamowski, 2013). The integration of natural elements into the urban context, including through the ecological regeneration of brownfield and underutilised sites (Ronchi et al., 2023), contributes to the strengthening of cities' resilience to environmental impacts and the improvement of the quality of life of their inhabitants (Atkinson et al., 2014; Giannakidou, Latinopoulos, 2023).

This is also the background of the Nature Restoration Law, approved by the European Council in 2024, which aims to reverse the decline in biodiversity and regenerate natural ecosystems, with the aim of restoring at least 20 per cent of the EU's land and marine areas by 2030 and, for urban ecosystems, a zero net loss of green spaces and tree cover, followed by a steady increase in their total area. This paper explores scenarios for the rehabilitation of public real estate aimed at fostering ecological regeneration within urban environments. It specifically addresses disused military sites, which frequently feature a combination of abandoned or underutilized structures and extensive open areas possessing substantial ecological potential. Regeneration is not limited to the functional rehabilitation of disused buildings and infrastructure, thus providing an opportunity for development without further land take but requires special attention to vacant and undeveloped areas. These soils, which may be either relatively natural or degraded from prior use, often require substantial efforts in renaturation and de-sealing to restore their ecological functions (Garda et al., 2023). In recent decades, the need to find new uses for military real estate has become increasingly urgent, following a process of rationalisation of military assets at a global level. This change has been driven by technological evolution, geopolitical changes and periods of economic recession, which have necessitated a progressive reduction in defence spending. A significant part of military real estate, used for centuries in national defence activities and now surplus to requirements, is being decommissioned and converted to civil

uses (Gastaldi, Camerin, 2017). The redevelopment of former military sites requires a strategic planning approach that diverges from conventional use changes. The complexity of the process is derived from the involvement of multiple stakeholders, the existence of different expectations, and the distinctive environmental conditions of the sites (Bagaeen, 2016). The value of brownfield heritage is frequently overlooked in territorial policies, with economic potential taking precedence over its intrinsic worth as a catalyst for urban development and wider territorial regeneration (Artioli, 2016). A frequently neglected aspect is the processual character of its origins, shaped by a layering of initiatives and settlement dynamics over extended periods. Additionally, in areas of substantial environmental and landscape value, it represents a valuable "common good" of collective interest (Agenzia del Demanio, 2012). The case study of the metropolitan city of Cagliari provides an opportunity to reflect on the opportunities offered by the inclusion of brownfield sites, long excluded from urban dynamics due to their original functions, in the framework of integrated territorial regeneration policies in an ecological key. This reflection comes at a very positive period, coinciding with the ongoing process of adaptation of the Municipal Urban Plan to the Regional Landscape Plan (RLP). The considerable availability of former military sites has the potential to serve as a strategic resource if incorporated into policies designed to address some of the most pressing challenges facing contemporary cities, including land consumption and the loss of environmental and ecosystem resources. In this context, attention is drawn to urban voids and residual open spaces, which are often overlooked regarding the reuse of the built heritage, despite their significant potential for urban planning.

2. Processes of decommissioning and rationalisation of military assets in the metropolitan city of Cagliari

The territory of Sardinia is characterised by a large military servitude, represented by infrastructures and sites that have lost their original functions but are still largely managed by the Ministry of Defence. The present study employs a multi-source approach, integrating bibliographic, documentary, and institutional website data, to reconstruct the historical evolution and actual territorial distribution of military assets. Historical cartographies, aerial photographs and institutional documents have been used to identify military areas and to understand their evolution over time. The cataloguing of military sites was also made possible thanks to the consultation and cross-referenced study of official documentation on conventions, inter-institutional agreements, protocols of agreement and programmes for the decommissioning and alienation of military assets that have been carried out over the years and that have involved the Autonomous Region of Sardinia (RAS), the Ministry of Defence, the State Property Agency and the territorial authorities. The data have been collected in a GIS database, which has allowed a detailed analysis of the characteristics, geographical distribution and current use of the assets, considering their interaction with areas of landscape value and historical-cultural assets.

A significant proportion of military servitudes are situated within the metropolitan area of Cagliari, encompassing an area of approximately 332 hectares between the municipalities of Cagliari and Elmas. These servitudes are distributed across the city, extending from the historic centre to peripheral areas such as Monte Urpinu and the promontories of Calamosca and Sant'Elia. In the wetland area of Molentargius, along the eastern part of the city, there are several military sites affecting an area of high landscape and environmental value, some of which decommissioned from time and currently unused, on which the Region of Sardinia has expressed its interest in the reuse, for example proposing the creation of an environmental centre. On the other hand, the largest and most important military facilities are concentrated on the Calamosca promontory, both in terms of extension and size of buildings, with a strong link to the historical defensive functions of the territory. These areas, once considered peripheral and mainly intended for agricultural and productive activities, have gradually been incorporated into urban settlement. However, their military function has helped to preserve their high landscape and environmental value, limiting intensive urbanisation. In this context, there

are also buildings of historical and cultural interest, such as a hillfort and a lighthouse, among the oldest in Sardinia. Most of the existing military buildings (barracks, residences, warehouses and other defence support infrastructures) are now in a state of abandonment or underused. Since 2006, the Region of Sardinia has carried out a census of military areas and buildings at regional level and has formalised a series of agreements with the Ministry of Defence to launch a programme of disposal of unused military areas, returning a significant proportion of these areas to the community. Due to the complexity of the administrative procedures required for the property transfer of assets, which are based on inter-institutional negotiations and require the investment of considerable resources in terms of cost and time, only a few assets have been transferred to the management of the local authorities (Colavitti, Serra, Usai, 2016).

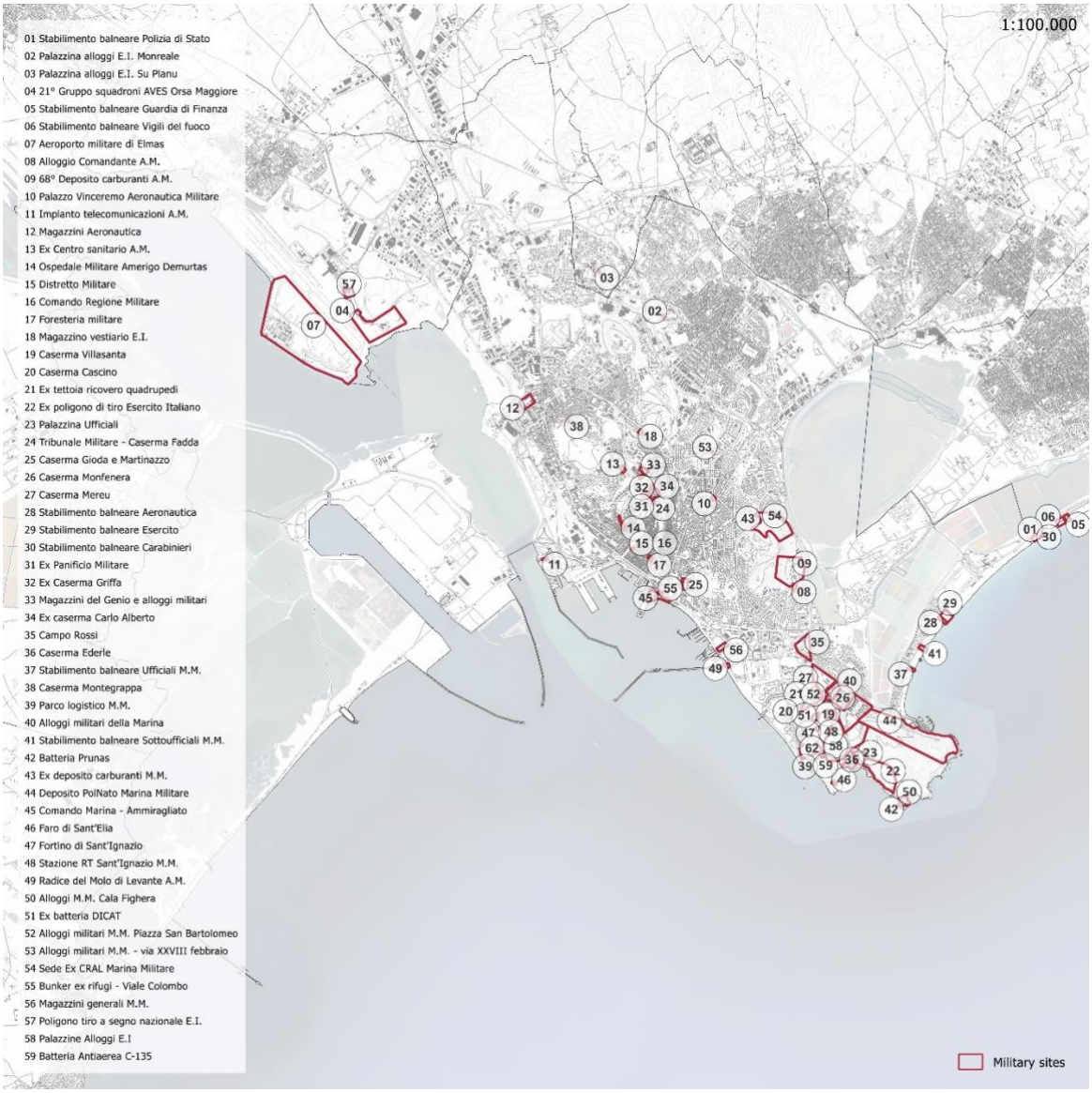

Fig.1 Military sites in the urban area of Cagliari

Some are decommissioned but formally used by the Ministry of Defence, while others are considered ready for transfer to the regional authority, as allowed by regional autonomy. Many abandoned military sites need new uses, and their progressive deterioration is not only a waste of resources but also a burden on local communities. Nowadays, projects mainly focus on the reuse of individual assets and prioritise their economic and use values, with the purpose of new functions linked to the provision of public services such as education, health, sport and leisure. In addition to the lack of projects, strategies and overall visions for the rehabilitation

and recovery of these brownfield sites, little attention is paid to the historical, cultural and landscape context in which they are placed. Public planning has historically prioritised large urban facilities within the consolidated fabric, as in the case of the transformation of the former Royal Arsenal into a museum, or the valorisation of assets of historical and cultural importance. Alongside these institutional initiatives, informal and grassroots practices of great importance have emerged, such as the creation of natural and archaeological routes, developed in collaboration between citizens, environmental associations and military institutions, have helped to preserve collective access to a valuable territorial heritage (Perelli & Sistu, 2015).

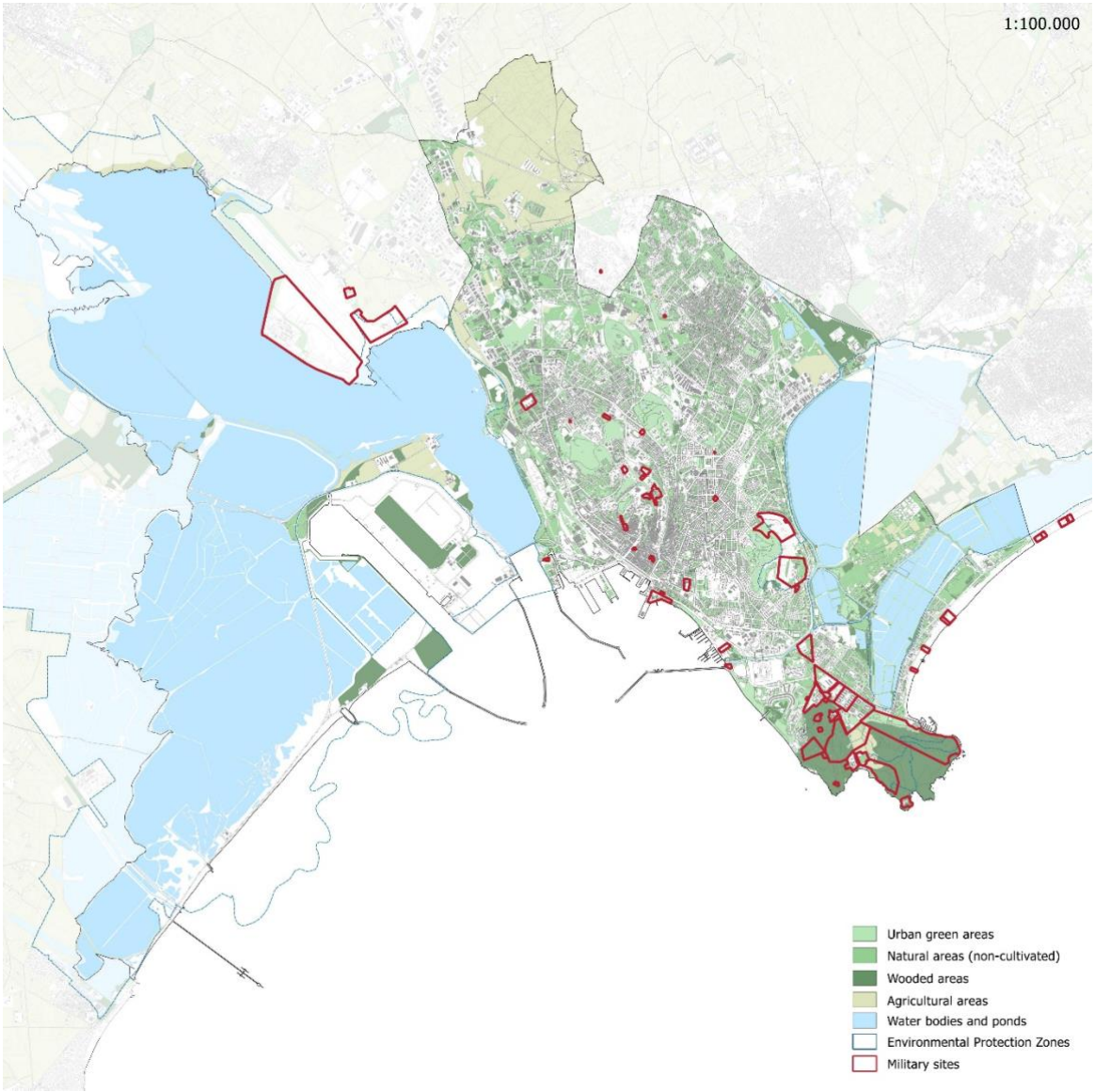

Fig.2 The ecological network in the urban area of Cagliari

The distinctive character of the Cagliari case can be attributed to the location of military sites within a landscape shaped by significant territorial invariants and environmental features, as delineated by the Regional Landscape Plan (PPR). The environmental components include the wetlands of the Santa Gilla Lagoon at the southern end of the Campidano plain and the coastal-territorial complex of Poetto and Stagno di Molentargius in the south-eastern area of the capital city, as well as the structural ridge of hills. These areas are managed under a range of environmental protection regulations that impose strict limits on development, such as Sites of Community Importance (SCI) and Special Protection Areas (SPA), where the conservation of natural habitats and species of flora and fauna must be ensured in accordance with EU directives. In this context, the

preservation of large areas of medium to high naturalness within or adjacent to military zones is particularly important, as these areas account for almost 40% of the military zones in the municipalities of Cagliari and Elmas. This high level of naturalness underlines the environmental value of these areas, despite their military use, and highlights the importance of maintaining ecological integrity and biodiversity in such strategic areas. In general, the issue of public real estate regeneration does not seem to find an adequate place in metropolitan development policies and urban planning. The adaptation of urban planning instruments to the PPR is very slow and suffers from the lack of sharing processes between the different stakeholders, experts and municipalities, which is usually the only apparently expected practice of this procedure. As a result, there is a lack of coherent strategies for the conversion of disused areas to civilian use. Cagliari's current urban plan identifies disused military areas as transformation areas, mostly for general services and sports, leisure, cultural and social facilities, often integrated into urban parks. The approach to the redevelopment of disused military areas has often privileged individual initiatives aimed at responding to specific problems or social demands, which have proved ineffective in the absence of coordination of interventions within an overall strategic framework.

3. The recovery of military brownfields for the ecological regeneration of the metropolitan area

The importance of military heritage at metropolitan level suggests the potential benefits of a regeneration strategy focused on enhancing environmental and ecosystem values, balancing the relationship between built and unbuilt land through the preservation and protection of land and natural areas. The development of settlements is a long-term historical process involving the community and the territory, based on a virtuous relationship between anthropic activity and environmental resources, conceived globally as a territorial ecosystem. Urban growth has been historically conditioned by the environmental dominants of hills and coastal wetlands, affecting the original forms of the natural landscape. The infrastructure system has often altered environmental processes, disrupting the hydrographic networks that feed coastal wetlands, although they remain an important reservoir of biodiversity and naturalness. The dynamics of metropolitan development have resulted in the convergence of settlements with significant implications for the health of urban ecosystems and the ecological corridors that facilitate communication between wetlands and environmental matrices. The regeneration of ecological corridors and networks connecting urbanised areas with agro-ecosystems has the potential to enhance the quality of living and production space, while also redefining the limits of urbanised areas (Magnaghi, 2000). This strategy reflects the design guidelines expressed in the Regional Landscape Plan (RLP), which assumes the priority objective of regenerating the Molentargius and Santa Gilla wetlands through the reactivation of environmental and productive uses with park-based forms of management. In particular, the RLP makes explicit the need for systemic management of the environmental components within the territorial macro-context, which are related in a relationship of mutual reciprocity, constituting a continuum of structural invariants of natural and ecological value, partially compromised over time by phenomena of anthropization and landscape modification (RLP, 2006). In line with these guidelines, the Municipal Preliminary Urban Plan aims to promote the connection between the Sant' Elia district and the coastal areas, proposing the regeneration and reuse of disused areas and buildings, including those owned by the State and the military that are currently being decommissioned.

The military servitudes located in the Calamosca and Monte Urpinu areas represent an opportunity to create an integrated and unified system of environmental and ecological protection, including wetlands and hills. This system would allow to counteract the process of urban expansion and the loss of green spaces by preserving green wedges and peri-urban agricultural areas.

For a long time, military use has isolated these areas from the surrounding urban fabric, preserving their natural characteristics and protecting them from processes of territorial transformation and the consequent

loss of ecological and environmental value. It has also preserved a significant number of areas free of buildings, particularly in the Calamosca area and, to a lesser extent, in the Monte Urpinu area. These regions are characterised by extensive permeable surfaces and a limited number of built volumes, which have often resulted in relatively low levels of soil degradation. However, it is essential to consider the potential for contamination resulting from long-term military use, as this could impact the quality of the environment and landscape, necessitating environmental restoration, remediation, and rehabilitation efforts. The strategy for regenerating these regions should encompass the enhancement of natural capital, aiming to both preserve and reinforce the ecological network that spans from the coastal zone, through wetlands, to connect with the ridge and urban parks of the Cagliari area, extending ultimately into the expansive peri-urban agricultural region to the north. This would ensure the preservation of the natural character of the areas in question, maintain a balance between urban development and nature, counteract anthropogenic pressures and promote biodiversity and ecosystem services. The de-militarisation of previously restricted areas would facilitate public access while ensuring compliance with environmental constraints and adherence to landscape and urban planning guidelines. Interventions should give priority to improving accessibility, removing perimeter fences that are no longer necessary and improving links with the main road network, including through a system of low-impact cycle and pedestrian routes. The planning of routes, considering the historical and cultural heritage of the area, will encourage the use of resources that have been isolated and difficult to access.

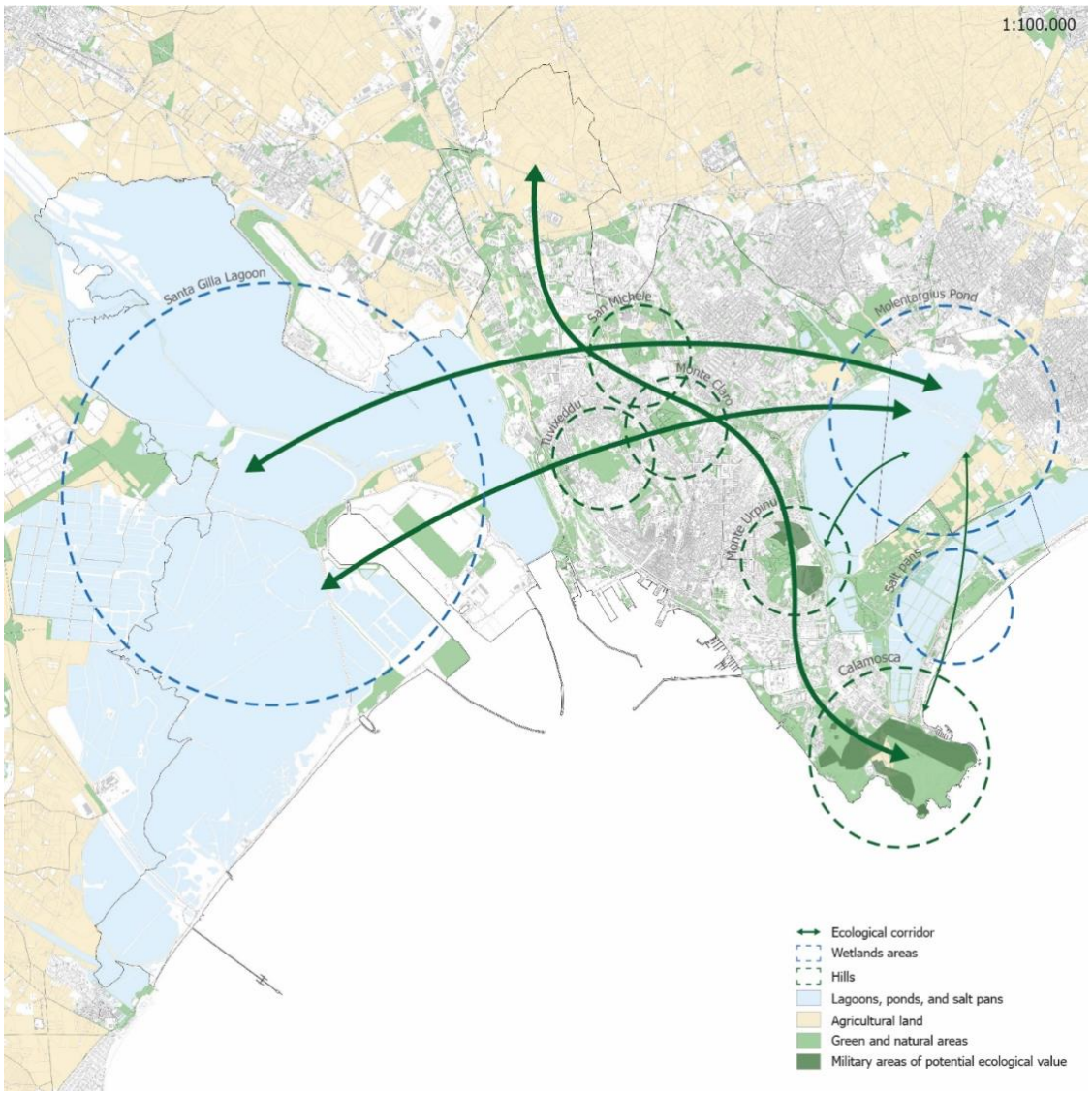

Fig.3 The strategies for the regeneration of disused military sites in the urban area of Cagliari

The safeguarding of disused military sites and the natural environment is significant at the territorial level, not only in terms of strengthening the ecological network of the metropolitan area, but also in enhancing the urban quality of surrounding neighbourhoods and potentially new districts in highly urbanised areas. In this way, disused public assets are reclaimed by the community for uses that enhance ecological functionality and facilitate territorial regeneration.

Strategies for the ecological regeneration of military land envisage a different approach for the historic barracks on the promontory of Calamosca, an autonomous urban system but currently separated from the urban context by walls and physical barriers. The removal of these delimitations is essential to favour the redevelopment and collective use of the spaces, improving the connection with the surrounding urban fabric.

The redevelopment of the military areas also includes the modernisation of the road network, with the integration of pedestrian and cycle paths and connections to public transport, promoting sustainable mobility. The objective of this intervention is to establish a novel integrated mobility structure that will facilitate connectivity between the city's residential and coastal areas, while leveraging the proximity of existing infrastructure, such as the recently inaugurated tram network.

The conversion of the military buildings, which were mainly intended for personnel accommodation, will allow the recovery and functional adaptation of spaces, avoiding the consumption of new land. The redevelopment will follow a functional mix criterion, introducing residential, commercial and service spaces, creating an integrated context both physically and socially. This transformation will also benefit neighbouring districts, such as Sant'Elia, characterised by public housing and a lack of public services.

The implementation of these strategies necessarily requires the co-participation and convergence of various public and private stakeholders, whose coordination can be facilitated by the design of instruments that provide a certain and shared basis to guarantee the satisfaction of the collective interest and, at the same time, the economic sustainability of the interventions. In this context, the public-private partnership model emerges as an effective approach for managing the financial planning of the intervention. It enables the provision of a housing stock designated for social housing at reduced rents, addressing the evolving social dynamics within the Cagliari area. This model meets the housing demands of middle-class residents, the elderly, and students, while ensuring a balanced social composition. Simultaneously, it allocates a portion of the housing to the free market to maintain economic viability, supported by the engagement of private investors.

In conclusion, the strategies described seek to combine economic profitability, recovery and a virtuous reinterpretation of these heritages with the objective of redefining the structure and organisation of certain parts of the urban and territorial system. This is to be achieved by calibrating the decision-making process in preparation for the definition of new uses and functions for these areas, with recognition of their collective and not exclusively physical dimension.

4. Conclusions

The EU Green Deal shapes policies for equitable and sustainable development by prioritizing both the ecological and digital transitions, which, though complementary, present distinct challenges and dynamics. The ecological transition, aimed at achieving climate neutrality and sustainability, demands extensive political and societal engagement, whereas the digital transition is a continually evolving technological process, predominantly driven by the private sector. In this context, cities are central and require innovative urban development strategies and planning approaches that integrate ecosystem services and promote urban sustainability (Moraci et al., 2024). In urban contexts, the promotion of biodiversity and ecological transition is closely linked to urban and regional planning at the local level, where the provision of new Green and Blue Infrastructures (GBIs) or the enhancement of existing ones can be implemented. The regeneration of Cagliari's urban areas affected by military servitude offers an opportunity to integrate the design of GBIs into the urban planning process, thereby promoting the restoration of environmentally, socially and economically fragile and

endangered ecosystems. The availability of timely and accurate geospatial data is critical for informed decision-making, improved understanding of ecosystem services and effective GBI planning (Giaimo et al., 2023).

A critical aspect involves aligning urban and neighbourhood-level projects with broader metropolitan and regional strategies and policies. Planning instruments need to work in concert, introducing measures to link environmental components and protect remaining natural, peri-urban agricultural and interstitial areas, to limit urban sprawl and maintain the continuity of the metropolitan ecological network. Military sites, by virtue of their size and strategic location, serve as new nodes within the metropolitan ecological network, contributing to the continuity of coastal systems and agricultural landscapes, while protecting important ecological corridors, including those connecting the two wetlands. Given the importance of this issue, it would be beneficial for local governments to develop a sector-specific strategic tool for the management and enhancement of urban green spaces. In Italy, the Green Plan has often fulfilled this role by integrating the objectives, strategies and actions of traditional urban plans, while identifying areas of significant landscape and biodiversity value for protection and enhancement. This tool helps to improve the ecological and ecosystem conditions of both urban and peri-urban areas, while promoting ecological connectivity (Lazzarini et al., 2024). Numerous studies have shown that urban green spaces are essential for providing cultural ecosystem services (CES) such as recreation, a sense of belonging, well-being and aesthetic values. Urban and spatial planning should consider the presence of UGS with significant ecosystem value within or near urban areas, as well as their accessibility and usability, to improve the overall performance of the urban environment in response to the needs of residents (Pantaloni, 2024).

The military presence has driven lasting processes of territorialisation, resulting in settlement contexts characterised by a combination of material and immaterial values embedded in local imagery. The case study of Cagliari illustrates the importance of ecological and environmental factors in shaping design scenarios for the reuse of decommissioned military assets. The processes of decommissioning of military assets in Sardinia is still hampered by bureaucratic complexity, regulatory constraints and high reclamation costs. The need for coordination between different institutions slows down the process, while regeneration requires huge economic resources that are often unavailable. In addition, social resistance and difficulties in exploring sustainable alternative uses contribute to leaving many areas in a state of neglect, limiting their potential for the community and the local economy.

The paper highlights the potential of real estate assets inherited from the military presence to contribute to a comprehensive strategy for ecological regeneration, beyond a mere focus on the reuse of existing built heritage. The protection of remaining undeveloped areas is crucial to maintaining an appropriate balance between the built and natural environment. The redevelopment of military sites, due to their scale and strategic location, provides an opportunity to enhance the existing ecological network of the city. This continuity can be restored through multi-scalar planning and the strategic integration of collective facilities, which are essential for improving the quality of residential and industrial areas. In this way, these under-utilised public assets can be repurposed for community uses and functions that not only improve the ecological functionality of the sites but also contribute to wider territorial regeneration.

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Image Sources

Images have been processed by the authors

Fig.1: Military sites in the urban area of Cagliari.

Fig.2: The ecological network in the urban area of Cagliari.

Fig.3: The strategies for the regeneration of disused military sites in the urban area of Cagliari.

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Civic Seoul 2030: toward infrastructural renaturalization

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Abstract
Citizens play a crucial role in shaping cities, balancing rights and responsibilities in public and private spaces. The concept of civic ethics involves finding a common identity within diverse individual differences and promoting sustainable urban ecosystems. Despite economic growth and formal democracy, residents of Seoul may not yet fully embrace this civic identity. Civic ethics call for a more integrated approach to city living, emphasizing values such as autonomy, empathy, diversity, and ecological awareness. Seoul's future development will be influenced by global trends in urbanization, requiring the city to adapt and plan strategically. The Metropolitan Government of Seoul is focused on inclusive growth, developing new engines for growth, and responding to changing demographics, but simultaneously on a process of decarbonization and renaturalization. To create a vision for 'Future Seoul,' the city is analyzing successful urban strategies from around the world and considering innovative approaches like a 'Civic City Seoul' model. In the light of a series of preliminary research, a number of architects are invited for our 'Underground' and 'Superground' projects. These projects reexamine various urban systems which used to be regarded as monofunctional and with a strong characterization related to urban renaturalization processes.

Keywords
Urban regions; Green networks; Territorial innovation

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1. Metropolitan renaturalization processes

Modern cities face unprecedented challenges: climate change, biodiversity loss, pollution, and a growing demand for green spaces for the well-being of citizens. In this context, urban renaturalization emerges as a promising strategy to address these challenges and improve the quality of life in urban areas. This essay explores the concept of urban renaturalization, focusing in particular on the transformation of existing infrastructure into natural corridors and its integration with public transportation systems and slow mobility. Urban renaturalization can be defined as the process of reintroducing natural elements within the urban fabric, often through the transformation of spaces previously dedicated to gray infrastructure. This approach not only aims to improve the urban environment ecologically, but also to create multifunctional spaces that can serve as both habitats for flora and fauna, recreational areas for citizens (Pirselimoğlu Batman et al., 2024), and corridors for sustainable mobility (Artmann et al., 2017), emphasizing the importance of integrating smart city growth with green infrastructure, creating a conceptual framework for compact, green cities. Early renaturalization initiatives focused primarily on the creation of urban parks and the restoration of isolated green areas. However, the contemporary approach has evolved toward a more integrated and systemic view that considers the city as an interconnected ecosystem (Pincetl, 2017), in fact, analyzing this historical evolution, highlighting how current urban renaturalization strategies are the result of a process of learning and adapting to emerging environmental challenges.

Fig.1 Strategic structure of the Civic Seoul renaturation project plan

The paper aims to retrace the choices made by the city of Seoul following the renaturalization of the Cheonggyecheon River, with the 'Civic Seoul' project (Fig.1) and the 'Superground' consultation and 'Underground' competition, projects in which the authors were variously involved. The very Cheonggyecheon River renaturalization project in Seoul, South Korea, completed in 2005, was a globally significant point of the

concept of renaturalization possibilities. This project involved the demolition of an elevated highway and the restoration of the river below, creating a linear green corridor in the heart of the city. The success of this intervention has inspired numerous similar projects around the world, demonstrating the potential of large-scale urban renaturalization.

Cities like New York, Paris, and Singapore have undertaken similar projects, each with unique local adaptations. For instance, the High Line in New York City has transformed an abandoned elevated railway into a public park, while Singapore's Park Connector Network offers a series walkways linking various parks and green spaces. These projects demonstrate the potential of elevated spaces to create new urban ecosystems, improve air quality, and provide residents with opportunities for recreation and social interaction. As cities continue to grow and evolve, renaturalization spaces are likely to become an increasingly common feature of the urban landscape. By learning from the experiences of cities like Seoul, New York, and Singapore, urban planners and designers can create more sustainable, resilient, and equitable cities.

2. Challenges for a social and re-nature Seoul metropolis

Throughout history, cities have grappled with urbanization. Seoul, like many others, underwent rapid growth since the 1960s, but has now reached a turning point. This presents an exciting opportunity to embrace the city's existing natural beauty, integrating historic development patterns with fresh approaches.

Moving past rapid expansion, Seoul, alongside other established cities, prioritizes human-centered urban regeneration. This strategy seeks to resolve past growth challenges while fostering organic development suited to the present. Additionally, Seoul faces the impact of transportation advancements, a changing demographic, and increased tourism – unprecedented issues requiring innovative solutions.

As cities mature, traditional urban planning approaches may reach their limits. Seoul is exploring architectural solutions as a lens to evaluate its future goals. This approach emphasizes the role of architecture within a broader urban design framework, recognizing buildings as interconnected with the city's fabric.

Citizens are individuals who possess both rights and responsibilities. As cities are spaces that serve both personal and public needs, citizens play a dual role as both inhabitants and contributors to the city's vitality.

The public realm exists between the private and social spheres. This means that public spaces require a balance of individual rights and collective responsibilities. Citizens must navigate this tension, embracing both personal interests and a sense of civic duty. As urban dwellers, citizens seek safety and security within their homes while also recognizing the need for compromise and cooperation with others. This involves balancing individual desires with the collective good. Citizens are expected to participate actively in their communities, communicate effectively, and work together to achieve shared goals. However, this often requires harmonizing seemingly contradictory demands, such as individuality and community, autonomy and cooperation. However, citizens come to establish a common identity within their respective identities as they accept and respond to such contradictory demands, and such a civic identity forms the center of the commonality, complexity, diversity, and organicity of urban spatial systems and prompts cities to function as immense and complex ecosystems. Of course, here also is the issue of the individual differentiation of various factors stemming from differences among individual citizens in class, gender, culture, education, experience, and geography. In addition, the differentiation of such individual differences and such complexity in themselves comprise the heart of urban ecosystems. These ecosystems signify the urban systems for survival, and efforts for the preservation and sustainability of urban ecosystems therefore become minimal morals indispensable to the maintenance of cities. They can also be termed an ethics that citizens must hold as the subjects of cities, and it is precisely here, too, that urban discipline meets civic ethics.

Despite a process of advanced economic growth and the establishment of formal democracy, it is difficult to say that the residents of Seoul as a megacity have sufficiently recognized or been trained in an ethics as co-subjects living together in common space. In general, citizens hitherto have tended to remain either capitalist

persons who pursue economic rationality and clearly recognize and claim private ownership or institutional subjects of formal democracy as represented by a sense of legal rights and political franchise, and these two identities have been divided or partly integrated according to the circumstances. Civic ethics signifies a more active and natural integration of these two identities, and such integration request citizens to grow into more creative and mature beings by rejecting and overcoming these two characteristics, which they currently harbor. Civic identity rejected as urban subjects signifies: thinking about Seoul not as an aggregate of fragmented individuals' efforts to survive without support but as a community of 'co-beings' living in common space (Bocca, 2021); pondering on what lies between the private sphere and the of social sphere; harboring humanistic values based on common identity including intellect, autonomy, coexistence, empathy, consideration, sense of responsibility, diversity, openness, and an ecological perspective; and having respect for the democratic values of engagement, communication, cooperation, solidarity, sharing, organicity, and peace. In addition, this implies the paradigms of urban planning for 'Future Seoul' beyond Seoul as a city of advanced growth based on economic rationality and Seoul's current identity as a symbol of square democracy (democracy prompted by demonstrations in open squares). Paradigms of 'Civic City Seoul' as well (Hae-Won et al., 2018). In the background of the task pursued by the Metropolitan Government of Seoul under the title of 'Future Seoul Tasks' lie the comprehensive awareness and long-term vision that the excavation of future leading projects and policy tasks for Seoul's sustainable growth is directly linked to the safety and prosperity of the Republic of Korea. The City of Seoul understands future tasks largely on the levels of inclusive growth, development of new growth engines, sustainable resilience (Shirgir et al., 2019; Palermo et al., 2024), responses to population changes and are creating related detailed execution plans. Consequently, the Basic Survey for the Urban Visions of Civic City Seoul presents specific strategies for urban spaces: grasping the complexity of the spaces encompassed by Seoul; analyzing the visions of major cities worldwide; deriving universal paradigms; and then proceeding toward 'Civic City Seoul' based on the zeitgeists of 'Civic Communities,' 'Condensed-sharing City,' and 'Ecological-humanistic City.'

According to studies forecasting the future of cities, cities in the future will encounter a reconfiguration of spatial, environmental, and social conditions that is utterly different from what has hitherto been experienced. In a situation where such changes in paradigms of urban development are accelerating, Seoul needs to overcome existing practices, to establish new perspectives on the strategic direction of urban and architectural policies reflecting changes in social structures, and to plan tasks accordingly.

Indispensable to preemptive discussions on the strategic direction of the urban and architectural policies of 'Future Seoul' is the advance construction of the basic data. In addition, it is necessary to examine urban strategies pursued from long-term perspectives in places including London, New York City, Paris, Catalunya, and Brussels as well, to look at the problems and strategies of cities worldwide together with Seoul's problems from multiple angles, to investigate advanced cases, derive new perspectives through active exchange, and to construct competitive basic data through discussions on international levels. Accordingly, the direction of future tasks will be established by analyzing the factors of change in urban environments that will affect 'Future Seoul' through the comprehensive collection and survey of the basic data on the internal and external elements surrounding 'Future Seoul' and the architectural strategies of major cities abroad and deriving future visions that will lead exploratory visions of mid- and long-term urban management policies and the transformation of urban policy paradigms.

2.1 Civic Seoul. Looking for n-scenarios

The next generation of urban planners will be challenged to find solutions to complex problems related to population, energy, environment, food, water, security, housing, health, and transportation. But also, to a rational land-use, a sustainable growth and infrastructural development, a new kind of conception of the public space, etc. Its challenge will be to provide new strategic scenarios no longer productive or reproductive but

'co-productive', capable of generating open and intelligent models, orientated and co-participated at a time, from which address, that talk about the new main global topics, substantial in the contemporary cities approach.

Fig.2 Schematization of all 10 paradigms of the Civic Seoul project in one scenario

The contemporary urban landscape is undergoing a profound transformation, marked by several key trends. One such trend is the emergence of new territorial articulations, leading to a renewed emphasis on re-naturalization, landscape valorization, and sustainable land-use practices. Simultaneously, public spaces are evolving into dynamic, interactive environments. The proliferation of sensors and real-time data applications is reshaping public interfaces, fostering new forms of civic engagement and participation. The concept of mobility is also being reimagined, with a focus on efficiency, speed, and slower, more contemplative modes of transportation. This shift is accompanied by a rethinking of infrastructure, leading to the development of integrated and sustainable models. Urban recycling and the reuse of existing structures are gaining prominence as strategies to reduce environmental impact and promote sustainable development. Moreover, there is a growing emphasis on mixed-use development, which involves the integration of various functions and programs within a single building or urban block.

Sustainable agendas, including energy self-sufficiency and resource management, are driving the development of eco-habitats and resilient urban systems. Cities are increasingly adopting flexible and adaptable strategies to withstand future challenges and ensure long-term sustainability. Coastal and riverfront areas are recognized as valuable assets, and their revitalization is seen as a key driver of urban regeneration. The tourism industry is also experiencing significant growth, driven by the increasing demand for leisure and cultural experiences.

Finally, the intersection of culture, innovation, heritage, and creativity is emerging as a powerful force in shaping the future of cities. By fostering these elements, cities can attract talent, investment, and visitors, and enhance their overall quality of life.

The Civic City Seoul urban spatial strategy (Fig.2) comes from the combination of the city urban system analyzed in the spatial resources section of the city. In principle, Seoul should be classified according to urban system classification in city area / natural area / infrastructure area / watershed area, and strategy appropriate to each area of unnatural territories (Canessa, 2021) should be applied. Urban spatial strategy defines the type of site or type of implementation as four single strategies:

- Central District | Target: It is a strategy that can be implemented intensively in the high-density area of Seoul. It aims to connect urban spaces of diverse character and lead new vitality and practice (Fig.3);
- Nature | Border: The goal is to create a city filled with vivid scenery, where urban elements and natural elements are intertwined by a strategy that can be implemented in the boundaries of Seoul and the surrounding countryside, or the boundary of Seoul and the city (Fig.4);
- Infrastructure | Clip: It aims to link various city infrastructure facilities such as bridges, transit, passage, park, and square in the fragmented city of Seoul, and to have an organic context at the whole city level (Fig.5);
- Water | Platform: The platform aims to extend and overcome Seoul's limitations through the transformation of perceptions of waterfront areas. Rather than introducing one functional element at the facility level, the platform sees the watershed as an alternative expansion of urban functions and plays a role of the integrated function of the city (Fig.6).

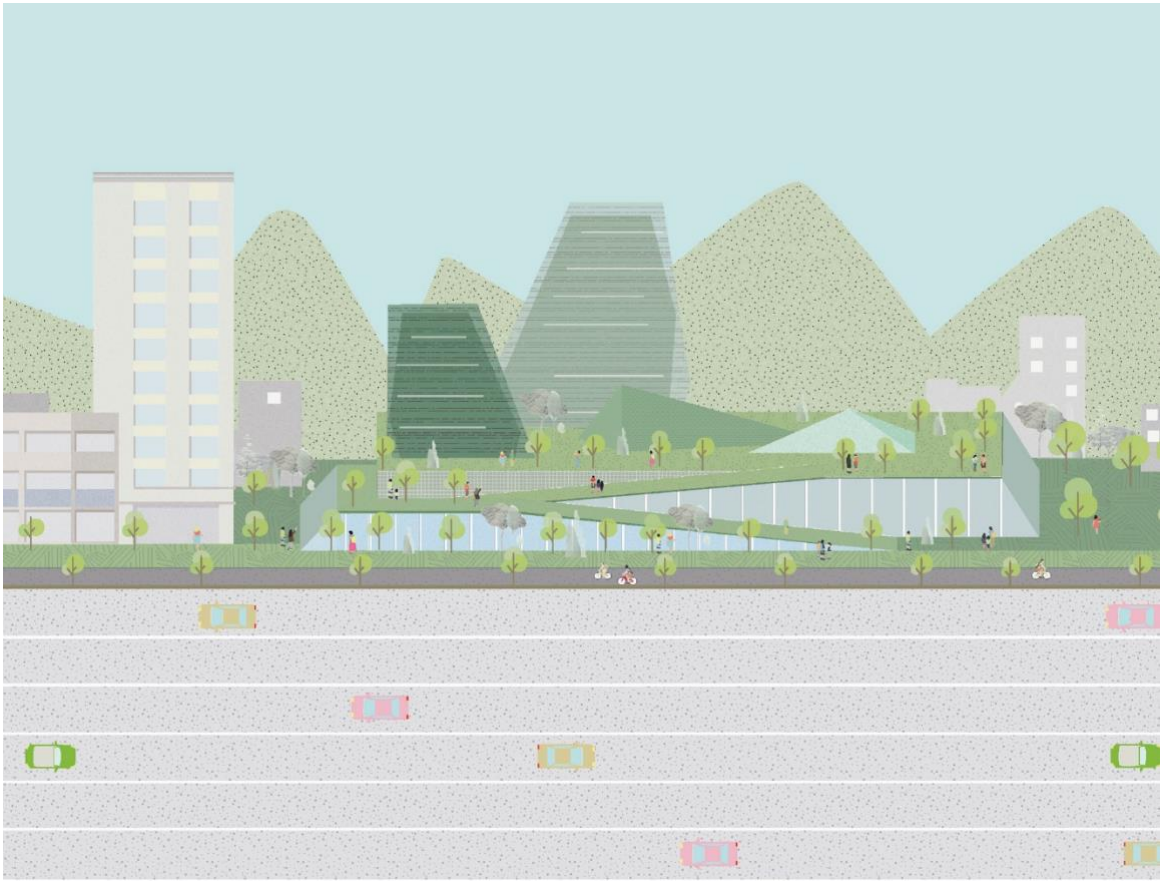

Fig.3 Central District. Simulation of a Target intervention

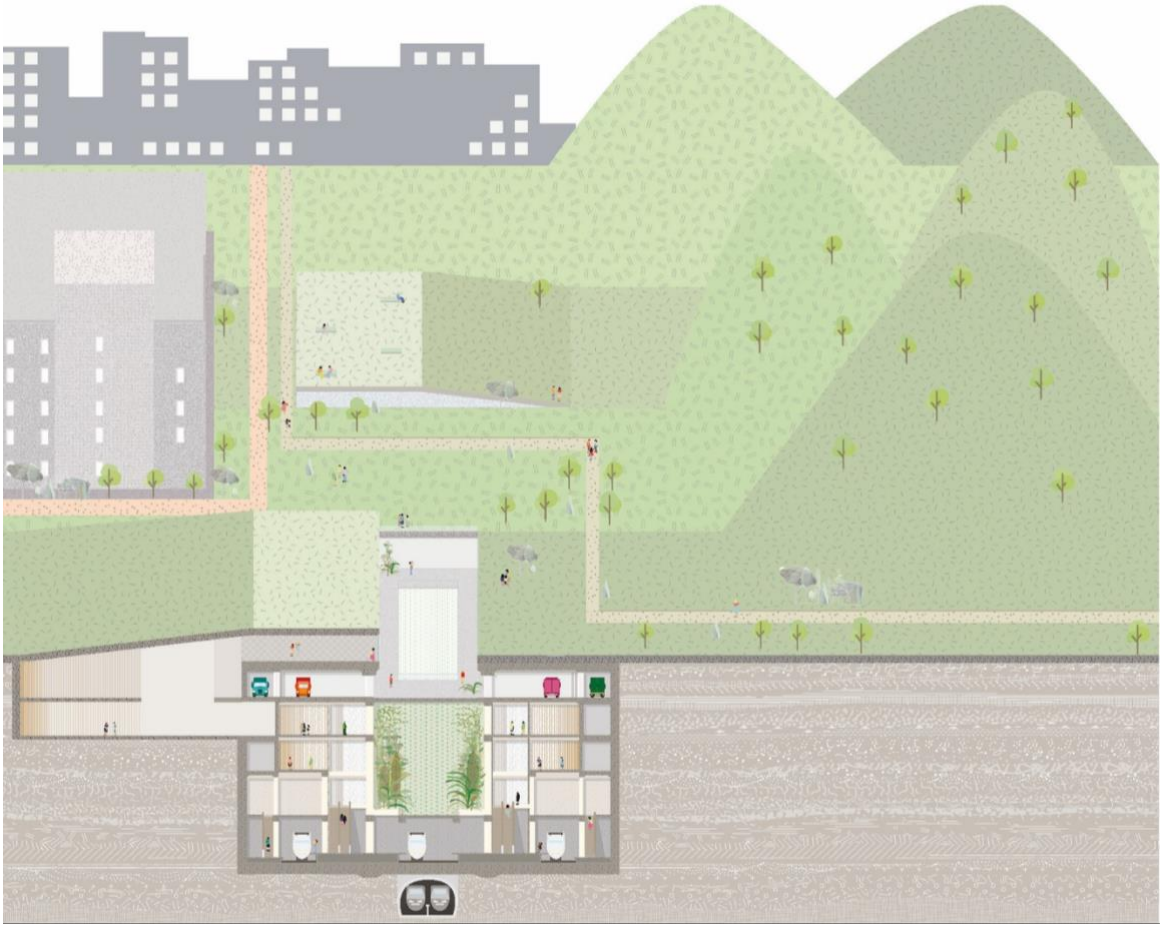

Fig.4 Nature. Simulation of a Border intervention

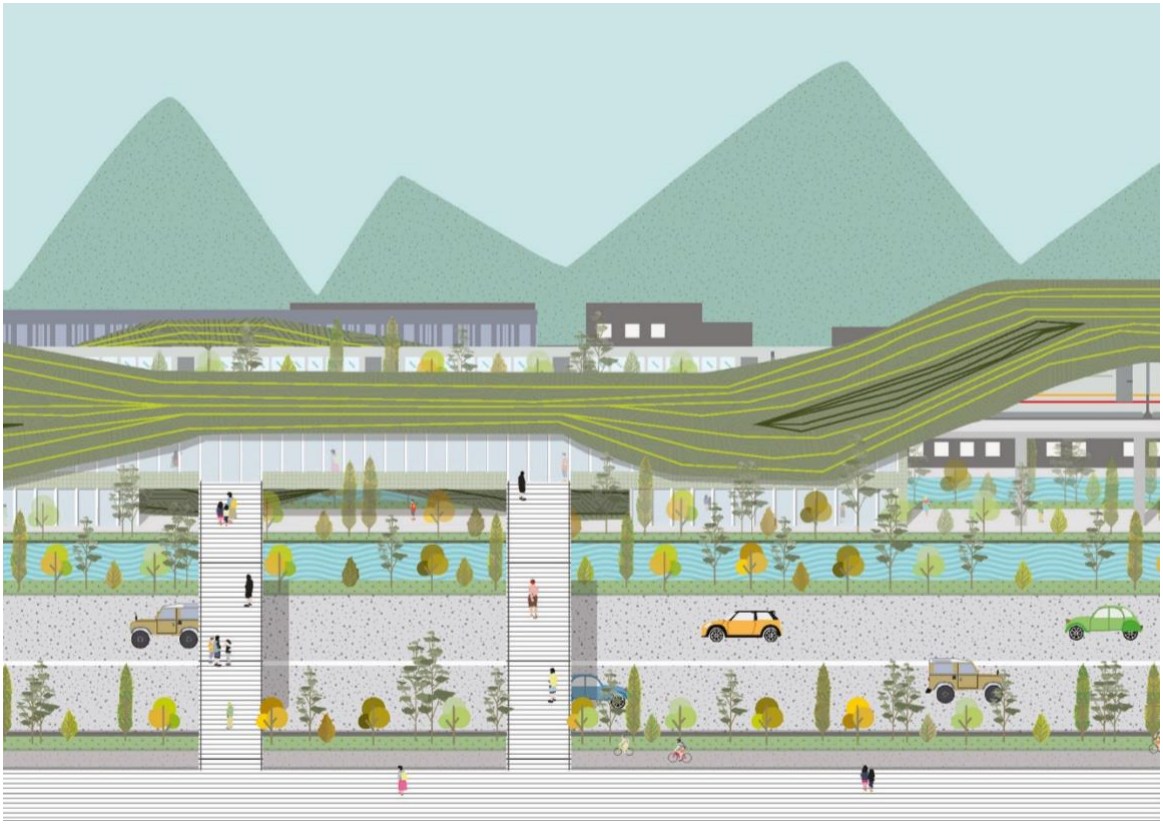

Fig.5 Infrastructure. Clip intervention simulation

Fig.6 Water. Simulation of a Platform intervention

2.2 Civic Seoul. Looking for n-scenarios

The 'Civic City Seoul - Ten Paradigms', which emerged from the study of the major cities in the world, are the local interpretation of various specific conditions that make up the identity of Seoul. These paradigms can be a basic principle of urban planning that can be applied to make Seoul a civic city, where the concepts of civic citizenship and renaturalization are forced into the context of a multi-scalar city like Seoul.

The last few decades have confirmed the evidence of a spectacular change of scale -and thinking- in the definition of our spaces of exchange and sociability -of our own habitats- to do with the exponential increase in mobility, (hyper)connectivity and long-distance communication, the delocalization of exchanges, and the capacity for technological and material transformation of our environment. But also, with the capacity to process and interact complex and digital parameters of information. Not yet, working 'from' complexity in order to simplify its effects, but working 'with' complexity in order to celebrate its potentials. Today, we are present at a change of paradigms in architectural thinking: from an architecture based on a static logic we have moved -or are moving- towards an architecture based on a dynamic and 'irregular' logic-one that is more impure, irregular and definitively interactive-in interaction with an environment, a context, a society and a creative and scientific culture permanently attentive to the diversity and complexity of a definitively informational space-time. Transversal and multi-scalar. The contemporary interest in tackling transverse fields involving urbanism, architecture and landscape responds to the interest in moving between boundaries, logics and scales (to recognize and to transgress them) but also to understanding architecture as a relational environment rather than a mere formal or functional object, with all that this implies in terms of constructional and interpretative, planning and (why not?) narrative interaction in and with the environment. Intersecting settings in which authenticity does not reside, then, in some kind of essentialist basis but in that open-ended process of interchange and interaction intended to work, at the same time with synthetic registers more than

with analytical layout n-scenarios (Fig.7): Urban and Natural Multi-Habitat; Participatory Civic City; Multi-centered Communicative Infrastructures; Sustainable Spatial Ecosystems; Reviving the City; Condensed – Common City; Resilient Urban Environment; Multilayered Boarder; Citizen-centered Tourism; Dynamic Cultural Heritage.

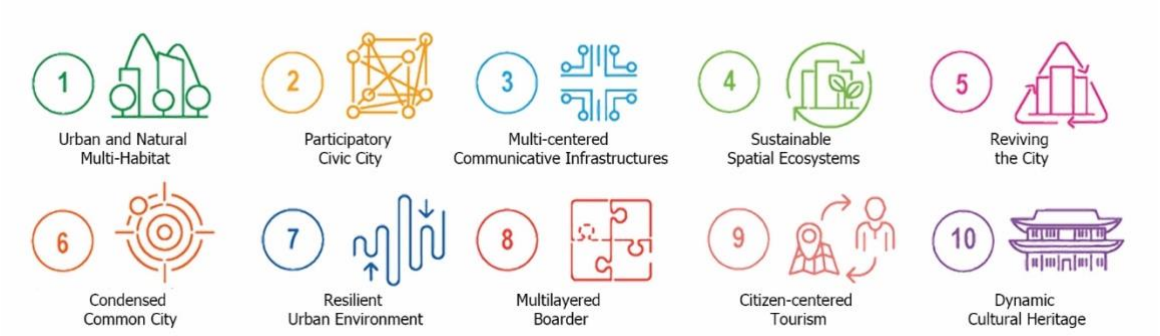

Fig.7 The 10 paradigms of the Civic Seoul project

2.3 Superground vs Underground

There exist indispensable infrastructures for a city to work properly. Currently, these infrastructures exist only to fulfill their functional purposes and are occupying huge areas in Seoul. Also, most of them are bringing isolation or disconnection to their neighborhood. However, today's advanced technology is helping them to explore possibilities for integration, complexation and going underground, and they have come to discover potential as a place to study new urban values. This research project has selected 20 sites for architectural and urban experiments to make Seoul into a city of people for the 21st century (Gausa, Joon, 2020). Some of these were assigned to teams of architects[1] to experiment with specific solutions and others were submitted to competitions such as the one won by Dominique Perrault Architecture to design the Gangnam International Transit Center.

In the light of a series of preliminary research, a number of architects are invited for our 'Underground' and 'Superground' projects. These projects reexamine various urban systems which used to be regarded as monofunctional. They look into underground spaces and infrastructures which were isolated from urban structures, with an aim to complement existing urban systems and prepare for the future. Though their discussions are around specific sites in Seoul, the ultimate goal is to find a universal solution applicable to other cities around the world.

The selected 20 sites can be classified into various categories such as size (XL, L, M, S), shape (Strip, Spot, Node) and type (Rail, Road, Water, Green, Waste).

The projects for each site are expected to be combination of following factors: Paradigm and Program. Among 10 paradigms for 'Civic City Seoul', some more than one, even all the 10 paradigms must be condensed in every site, evaluating the different degree of a percentage by each participant. In the same way each participant must evaluate the percentage to be attributed to each of the 4 Programs (Living Spaces, Convivial Spaces, Production and Exchange, Knowledge and Leisure).

Is easily recognizable a game of transitions, made by transits by and from 'territory to city to place and then to project': from the exploration of new types of evolutionary devices called to combine information and conditions, programming and formulations, into new maps of analysis and synthesis at the same time. The goal of this 'strategic-expressive' methodology is to re-evaluate urban reality analyzed, re-activating it from its

[1] AZPML, Eduardo Arroyo — NO.MAD, Chanjoong Kim, Eun Young Yi, Studio Fuksas (Massimiliano and Doriana Fuksas) + Ramon Prat Homs, Go—Up Architects, Haewon Shin, Alejandro Haiek Coll, Minsuk Cho – Mass Studies, Willy Müller – WMA, NL Architects, Seung H-Sang, IROJE architects & planners, Francis Soler, It's, Michel Desvigne, Federico Soriano and Dolores Palacios — S&Aa, Topotek 1, Yoshiharu Tsukamoto — Atelier Bow-Wow + Tokyo Tech. Tsukamoto Lab, Charles Waldheim + Office for Urbanization, Yoon Gyoo Jang — Unsangdong Architects Cooperation.

own articulated potential, that is, from its own resources and active elements. (re-evaluating its dynamic impulses and its structural matrices and, at the same time, revalorizing its space models that are potentially more qualitative).

The process is developed in a sequence of steps that begin with the 'Questioning the city and the territory', proposing (recording, expressing, displaying) big latent questions - explicit or implied - associated with datas (information documents) and evolutive informations (processes), creating a systems that is able to stimulate possible criteria (answers), associated with those resources and latent elements (potential) to which we must give impulse and orientation, and so, to possible urban horizons (objectives) and the resulting challenges. Objectives that would, in turn, suggest urba-bets, and possible future scenarios and, therefore, intentional vectorization (strategies); objectives that would be declining and formulating themselves - in an inductive / or activating way - as concrete proposals and which, involving key spaces and programming (situations) would lead to concrete operations. These interpretative keys of reading, condensed into synthetic visions, and articulated process leed to express new relational frameworks for the city: local and global, global and local, at the same time.

3. Conclusion

The 'Civic Seoul' project and the 'Superground' and 'Underground' consultations, move toward a sometimes extreme re-naturalization, where only a megacity like Seoul can think of playing a decisive role today by imagining changing course by phasing out cars, burying its infrastructure, and giving back space to nature and citizens in a social condition of exponential population growth that would seem completely at odds with this trend, but perhaps it really is a forward-looking and perhaps viable solution with great cohesion between public and private investment.

Despite the many benefits, implementing urban renaturation projects presents several challenges. Cost is often a significant obstacle, as the transformation of existing infrastructure can require considerable investment, both for implementation and long-term maintenance (Kabisch et al., 2016), with the need to develop innovative financing models to overcome these barriers. Renaturation can conflict with other urban land uses, requiring a careful balancing of different needs (Haase et al., 2017) with the need to adopt integrated planning approaches to maximize the benefits of urban renaturation. Integrating natural elements with existing infrastructure requires interdisciplinary expertise and can present significant technical challenges (Ahern, 2013), combining ecological, urban planning, and engineering knowledge. Some interventions may face community resistance, especially if perceived as a threat to established habits (Buijs et al., 2016), increasing the importance of involving citizens in decision-making and transformation processes. However, these challenges are accompanied by numerous opportunities. Technological innovation is making renaturalization projects more feasible and effective. The development of new technologies, such as bioengineering systems and permeable materials, is expanding the possibilities for interventions (Zölch et al., 2017; Papa et al., 2021), including through the application of nature-based solutions for climate change adaptation in cities. The economic benefits of urban renaturation represent another important opportunity. The creation of nature corridors can lead to increased property values in surrounding areas and create new economic opportunities related to tourism and recreation, where urban green spaces can act as catalysts for social interaction and community engagement.

Urban areas are facing unprecedented challenges, including climate change, population growth, and infrastructure aging. To address these issues effectively, cities must adopt innovative strategies that leverage technology. Digital twins, virtual representations of physical assets or systems, have emerged as a powerful tool for urban planning and management (Weil et al., 2023). By creating a digital replica of a city, planners and decision-makers can gain valuable insights into urban systems, enabling them to make data-driven decisions and optimize resource allocation.

Digital twins offer several advantages for urban planning. First, they enable real-time monitoring of urban systems, allowing planners to track changes in traffic patterns, energy consumption, and environmental conditions. This data can be used to identify potential problems and inform timely interventions. Second, digital twins can support predictive analytics, enabling planners to forecast future trends and assess the impact of different policy scenarios. This capability is particularly valuable for addressing challenges such as climate change and population growth. Third, digital twins can facilitate optimized resource allocation by identifying inefficiencies in urban systems. For example, a digital twin can be used to optimize the location of public services, such as schools and hospitals, to improve accessibility and reduce travel time.

Digital twins represent a paradigm shift in urban planning. By providing a virtual replica of a city, digital twins enable planners to make more informed decisions, improve infrastructure management, and foster sustainable development. As cities continue to grow and become more complex, digital twins will play an increasingly important role in shaping the future of urban environments.

Finally, urban renaturalization offers important synergies with other urban policies. Renaturation interventions can support other urban policy goals, such as regenerating blighted areas and promoting sustainable mobility (Raymond et al., 2017), all co-benefits of nature-based solutions in cities. To maximize the success of urban renaturation projects, a strategic and integrated approach is essential. Long-term planning is critical for renaturalization, which should, as with Seoul, be strategically designed for the long term, considering future projections of urban growth and climate change.

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Image Sources

Fig.1-7: Images accompanying the Civic Seoul project by the paper's authors.

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Towards bicycle infrascapes. Active mobility as an opportunity for urban regeneration and open space redesign

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Abstract
With mounting urban challenges such as climate change, pollution, traffic congestion, and sedentary lifestyles, cities worldwide are rethinking their policies, and two concepts are at the forefront of this transformation: active mobility and green infrastructure. Active mobility prioritizes modes of transportation like walking, cycling, and using micro-mobility solutions (e-scooters, e-bikes), while green infrastructure strategically integrates natural elements into the urban fabric. Remarkably, when active mobility and green infrastructure are coupled, the impacts become amplified, offering a powerful solution to create more liveable, sustainable, and equitable cities. With a particular focus on diversified greening trajectories for cities, this contribution wants to trace a comparative exploration in the frame of *Bicycle Infrascapes* research developed by the GICLab of Genoa University, aimed at defining a framework of international urban design and landscape projects where the notion of green infrastructure become multi-fold especially when connected to the reorganisation of mobility patterns and open space re-design.

Keywords
Bicycle infrastructures; Active mobility; Multi-modality; Open space; Post-car cities

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1. An open multifunctional interpretation of green infrastructures

In recent decades the concept of *Green Infrastructures* (Benedict & MacMahon, 2006; EU, 2013), understood as a variable geometry network of natural, semi-natural green areas and other open spaces designed to foster multifunctional environmental features for urban communities and beyond, has become widely established. (MEA, 2005; Mell, 2010; EEA, 2011; Austin, 2014; Galan, 2015; Artmann et al., 2017; Ying et al. 2022) Parks, water bodies, riverfronts, street boulevards, public gardens, ecological corridors, ecotones, urban-rural fringes, agricultural spots, wetlands, urban woodland, pedestrian and cycle routes, community spaces, sport fields, school grounds, allotment gardens, leisure areas, are among others the variable components and integral parts of scattered or continuous green infrastructures. (Natural England, 2009; British Design Council, 2013; German Federal Agency for Nature Conservation BfN, 2017).

Although the term has been adopted in academic debate, research and planning documents to support environmental conservation principles through actively maintaining, restoring, and supporting ecosystem services and green connectivity, today green infrastructures expand its range of applicability in a multi-fold and systemic perspective (Naumann et al., 2011; Ying et al., 2022). In fact, one of the best and most appropriate planning tools based on this approach is the application of green infrastructures to counter-balance urban development impacts, by redefining the relationship between biotic (people, flora, fauna), abiotic (soil, water, air), cultural and artificial (buildings, roads, infrastructure) components of an urban ecosystem (Brady et al., 2001; Schäffler & Swilling, 2013). It implies a condition far from any state of permanence, particularly when related to the assessment of service provision, the reorganization of functions, adaptability, and alternative forms of stability through locally generated positive externalities.

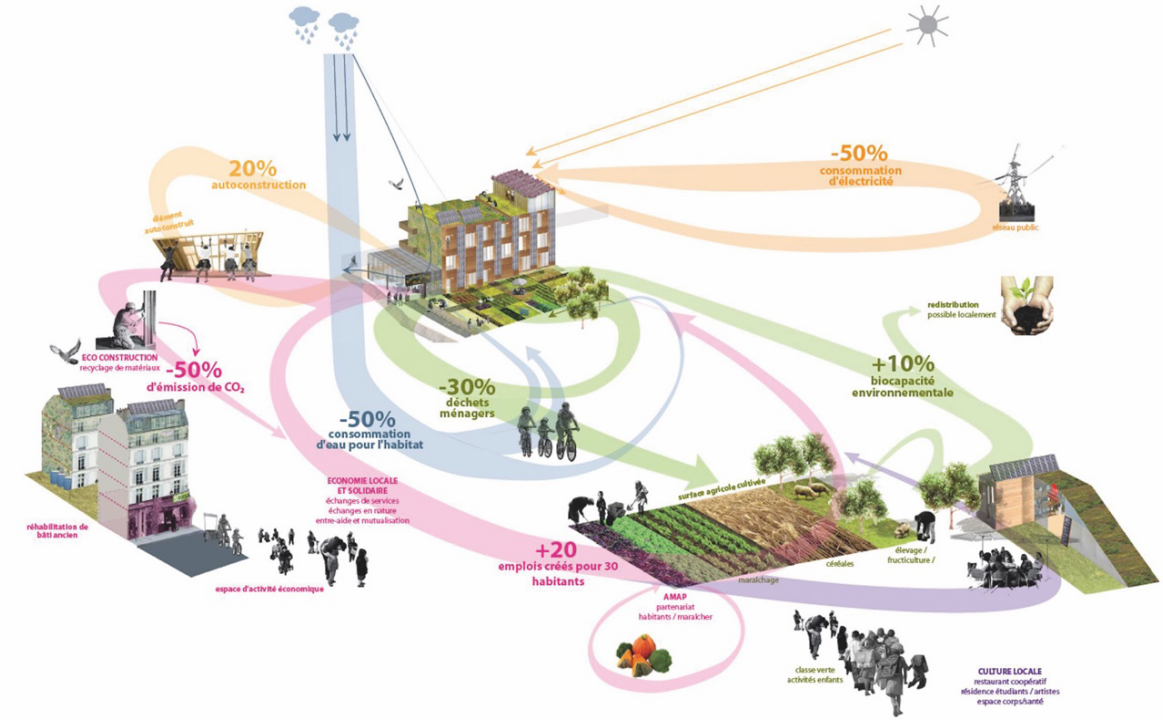

Fig.1 Diagram of green infrastructure components and its mutual relationships to foster resilience and active living

In this way, due to its multifunctional character, a green infrastructure inherently encapsulates a spatially and strategically idea of *ecological resilience*[1] among its components (Holling et al., 2002; Wright, 2011; Mell et

[1] The idea of resilience has a long history in ecology and engineering, but its application to urban and recovery planning is relatively recent (Berkes 2007). In engineering, resilience is concerned with disturbances that threaten the functional stability of materials and infrastructures. In ecology, Holling (1973) uses resilience to describe an evolutionary process of ecosystem dynamics towards different forms of stability. The two concepts are used in hybrid systems theories and

al., 2017). Consequently, it needs to be delivered fostering natural green potentials at every scale of intervention and aggregation on different semantic levels: from the local neighbourhood pockets parks to every kind of urban surfaces, even those not originally conceived to accommodate ecological functions, towards larger territorial *land-links* (Gausa, 2020) which contribute to urban well-being such as metropolitan greenbelts and territorial eco-structures (Fig.1).

As Wright (2011) points out the ambiguity that accompany the definition of green infrastructure, relates to the complex and operative nature of the concept, which inevitably evolves and develops in relation to different uses and contextual conditions. At the same time, it represents an integrative approach aiming to bring together multileveled stakeholders around common societal objectives with different application areas, such as open space re-design and landscaping, climate adaptation, remediation and nature-based solution, public transportation and active mobility (Gargiulo & Sgambati, 2022; Oguz & Tanyas, 2024), city attractiveness, livability and social cohesion (Fink, 2016; Frantzeskaki et al., 2017; Anguelovski et al., 2018). Extending this notion and designing more effective greening trajectories for cities pass by the capacity to enhance the unexpressed potentials of every kind of urban surfaces, even those not originally conceived to accommodate eco-infrastructural functions (i.e., backyards, parking spots, vacant plots, infrastructural corridors, state-owned areas, collective commons, rooftop surfaces in line with the typological reinvention of residuals (*délaissé*) and fallow lands (*friche*) as exposed by Gilles Clément in the *Manifesto of the Third landscape* (2005).

As such, the architecture of a green infrastructure has evolved into a processual (design-oriented) approach, which implement open configurations and diverse connectivity of natural-mediated elements able to adapt to heterogeneous urban ecosystem demands and diverse landscape functional treatments. (Band et al., 2005). In this regard, urban open space can be a pivotal area for green innovation, by directly affecting the quality of peoples' daily lives. Promoting awareness regarding the socio-economic impacts of green infrastructure development, at different spatial and temporal scales, can nurturer environmentally impoverished contexts, such as urban streetscape, becoming a valid means of compensating and mitigating the impacts generated by the traffic congestion and metropolisation of the territory. It is a strategy that facilitates the transition to car-free cities, even in densely populated regions, by overcoming the relational ontology of 'City-in-Nature' or the dialectical dualism of 'Urban landscapes' and 'Nature and Society' (Swyngedouw et al., 2005; Moore, 2011).

1.2 Surface re-design and new potentials for urban ecological transition

Although the articulation of urban green systems has increasingly gained prominence in public debate and urban agendas (Pultrone, 2023), by supporting participation in health-enhancing physical activity in daily routine through the *Active Healthy Cities* approach (Duhl, 2005; Edwards & Tsouros, 2008; Dorato, 2020), the care and equitable access to safe urban space has not accounted the same attention.

People are willing to walk or bike if the surroundings provide them with a pleasant wandering on safe routes passing through public green spaces. Steven Mouzon calls this 'cycle-pedestrian propulsion' (2010): a beneficial side effect that prompts people to travel a longer route than necessary, if properly compensated with a qualified journey experience. In this way, enhancing urban attractiveness and street life represents a significant driver for successful placemaking interventions and green infrastructure development. Promoting a vibrant urban experience, enhancing the sense of place by encouraging inclusiveness through open space re-design are the main principles to guide the reclamation of underused space from vehicles or other grey infrastructures. As demonstrated by numerous high-profile urban recycling projects (Ciorra & Marini, 2011;

socio-ecological systems (Berkes, Folke 1998), but in relation to green infrastructures, they mostly concern the effective mitigation of urban environmental deterioration, ensuring local ecological security, and maintaining spatial sustainability. (Lennon & Scott, 2014).

Ricci, 2012), such as the High Line in New York[2] or the Elevated Garden of Sants in Barcelona[3] (Fig.2), the recycling of rail mobility infrastructure to create new urban connections, pathways, and design possibilities can increase property values, potentially driving speculative tendencies and gentrification. Nonetheless, these projects also foster new layers of accessibility and sociability, provide escapes from urban congestion, and enhance aesthetic quality in dense urban environments.

On the other hand, especially in situation of peripheral contexts or of diffuse urban sprawl, the quest for urban sustainability is more and more connected to the role, qualities and characteristics of the public space structure (Bell, 2012; Haase et al., 2020). Planning the new post-urban condition when places become both dense and diverse it means thinking not only the spatial form of the cities, which is always subject to change, but to conceive its forms of aggregation on urban streetscapes, where the principles of walkability and cyclability becomes new quality standards, as well as to strive for resilience or adapt to climate change when planning for and managing urban concentrations (Gausa, 2012; Costa et al., 2014; Gausa, 2020). Beyond boosting neighbourhood morphological qualities, making mobility infrastructures aesthetically and functionally appealing for citizens is a matter of urban and landscape design, optimizing their limits/borders accessibility through multifunctional programs (Beatley, 2012). If the manipulation of surfaces has been always a constant for landscape design, transforming an element that usually bears a flat coding into an active, complex, mutating field can inform also new mobility pattern and functional options to the streetscape. The exploration of new multi-level surfaces for public space use is central to MVRDV's temporary project for the Rotterdam Rooftop Festival. The Walk allowed visitors to experience pathways at a height of 30 meters, showcasing new possibilities for rooftop reuse (Fig.3). Many of the most promising ideas, in this regard, are the reformulation of the *in-betweens* (Gausa, 2009): partitioning of open spaces and articulation of clustered activities, which don't fit neatly together, but producing new integrated land-uses, including quirky, jerry-built adaptations or additions to existing functions with the intent of promoting *urban mixitè* and ultimately facilitate the potential of new scenarios for active, safe and sustainable mobility.

Drosscapes, terrain vague, residual surfaces (Berger, 2007; Barron & Mariani, 2013; Gasparrini & Terracciano, 2017) open up new areas of applicability for green infrastructures. The last few decades, in fact, have confirmed the evidence of a renewed demand of accessible and quality public spaces, place of exchange and networking in our daily life. Vital to sustain civic engagement and co-creation of changes through flexible solutions —as experienced during the pandemic period, when social distancing measures have shown the limitations of our public reorganization of logistic and mobility systems— the active mobility and green infrastructure, when coupled, can sustain the extension of green mobility lines, offering a powerful solution to increase porosity and permeability of the urban fabric. In this regard, urban designers are tasked to make the streetscapes a significant and attractive experience capable of diverse uses on different temporal patterns, according to the concept of shared streets, for which the beautification through landscaping, urban mixite and wayfinding become important features.

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[2] The High Line (2006-2009) is a linear park designed by Diller Scofidio + Renfro and Field Operations, on a disused section of New York's West Side Line. Since the founding of the Friends of the High Line organization in 1999, the local community has mobilized to transform the infrastructure into a public space. Numerous workshops, forums, and meetings were held to gather community input, leading to the launch of a design competition for the park. The result is an elevated pedestrian pathway that alternates between landscape-inspired "rooms" featuring gradients and colors reminiscent of pioneer plant species. The High Line is part of a broader urban strategy to promote a more livable, sustainable city, with a strong focus on soft mobility. In this sense, it complements New York's cycling infrastructure. For more info see Dimendberg E. (2013).

[3] The Elevated Gardens of Sants (2016-2018) covers a the main est-west railway and metro corridor in Barcelona, creating a new urban connection over a complex artificial topography rich in plantings of shrubs, trees and ground cover. Designed by Godia + Molino Architects, the elevated gardens constitute a new 5km green corridor with pleasant terraces and bike path. Retrieved from: https://urbannext.net/raised-gardens-in-sants/

Shifts in urban planning practices have revealed desires by both residents and local governments to embrace the idea of complete or shared streets, as a «convenient open space re-organization, environmentally rich in nature-based solution, safe, comfortable, suitable for inter-modal shift between private cars, foot, bicycle, and public transport, regardless of age and ability». This change in dynamics places an emphasis on reorienting roads mainly for pedestrians and their movements freedom, towards multiple transit options within a network, requiring connectivity hubs according to a Transit Ordinated Development hybrid model (Cervero et al., 2002). While green infrastructure is important, it alone is not sufficient for achieving a healthy and green urban environment. Therefore, as underlined by the Urban Agenda and the EU Thematic Partnership 'Greening Cities', the integration of green infrastructure into other sectors – beyond the protection of biodiversity and addressing the climate challenge – is of high relevance. In the same vein, as greening cities is a holistic concept, it is important to approach the theme in a more integrated manner coupling green infrastructure and urban open space design, particularly intertwining other policy areas such as traffic reduction, clean energy transition, sustainable mobility, urban regeneration, circular economy (Franco, 2023) and public health.

Therefore, a growing number of projects are experimenting street-space reallocations fostering intentional, programmatic and temporary re-design of street functions, manipulating surfaces, limits configuration and multi-modal regulation to explore systemic change in urban mobility (D'Amico, 2023; Lahoorpoor et al., 2022). In this regard, "Bicycle Infrascapes: bicycle mobility towards responsive public cities" research project (UniGe-PRA 2022) defined an international collection of 18 urban design and landscape projects, where the notion of green infrastructure becomes operational for its transformative impact related to the reorganisation of urban surfaces and able to promote a wide spectrum of applied strategies to foster cyclability and walkability in cities. The investigation aims to build a framework of international experiences in urban and territorial design for new infrastructures dedicated to active mobility, focusing on projects that are either completed or currently under implementation.

Fig.2 Elevated gardens of Sants: linear park and new urban connection in Barcelona (2016-2018)

Fig.3 Roofscape reuse fosters the transition to a multi-layered green city during Rotterdam Rooftop Festival (2022)

2. Operational options of green infrastructure to support new urbanities

Moving towards a walking world requires actions. These actions concern visions and strategies, safe and efficient transport systems, creating liveable environments, sensing place conditions and implementing responsive solutions. The practicality of these actions is illustrated by a series of emerging figures and case studies from across the world. The selection criteria adopted for case studies insight for *Bicycle Infrascapes*, range from place-making effects produced by urban design-oriented projects through the definition of new green infrastructures, the re-naturalization of post-metropolitan contexts, the enhancement of urban resilience as well as the opportunity to upgrade infrastructural programme though new meanings and new values. All the projects deal with significant regeneration programmes produced in place, the creative reactivation and reuse of existing infrastructures and the enhancement of green actions able to support *Context Sensitive Solutions* (Dondi et al., 2011; Laaly et al., 2017; Kraus & Koch, 2020) applied on 3 key-figures of intervention on public space[4]. Responding to this challenge, this paper aims to collect multiple perspectives and contributions that support context-sensitive bicycle infrastructure designs, by considering community' values and perception on landscape enhancement produced in place after the completion of these interventions as well as their perspectives on necessary trade-off choices.

The identified case studies focus on both the repurposing of infrastructure and new forms of active mobility across three themes of public space intervention. These projects were analyzed to uncover multiple

[4] Context Sensitive solutions, firstly introduced in 1998 International Conference 1998 'Thinking Beyond the Pavement', refer to holistic approach for road reorganization wherein safe transportation solutions strive to balance functional, scenic, aesthetic, environmental and natural resources, as well as community demand for new user-centered transportation services, such as demand responsive transport, bicycle highways, active public spaces. See: Stamatiadis, N. & Hartman, D. (2011); Hilbers, A.M. (2024)

approaches within different territories, categorized through a multidimensional classification: territorial scale, urban scale, and local scale.

- *Management of Climatic Events:* The adaptation of obsolete or non-functional infrastructure to manage climatic challenges is reconsidered for the seasonal use of public spaces through new infrastructure, nature-based solutions, and enhanced accessibility.
- *Re-naturalizing Ecosystems:* The projects analysed enhance socio-ecological structures, promote multi-species ecosystems, and increase biodiversity with an ecosystem-focused approach.
- *Inhabiting the Infrastructure:* The redesign of disused or previously inaccessible infrastructural areas increases the quantity and quality of public spaces through a multi-use and multigenerational approach, redefining these spaces for local communities.

2.1 Management of climatic events

Rethinking public space infrastructure to address climate and environmental challenges creates opportunities for new forms of active, accessible mobility (Clemente, 2022) and stronger connections with public domain. New York City, severely affected by Hurricane Sandy in 2012, needed to rethink an integrated coastal infrastructure to overcome its vulnerability (NYC, 2020).

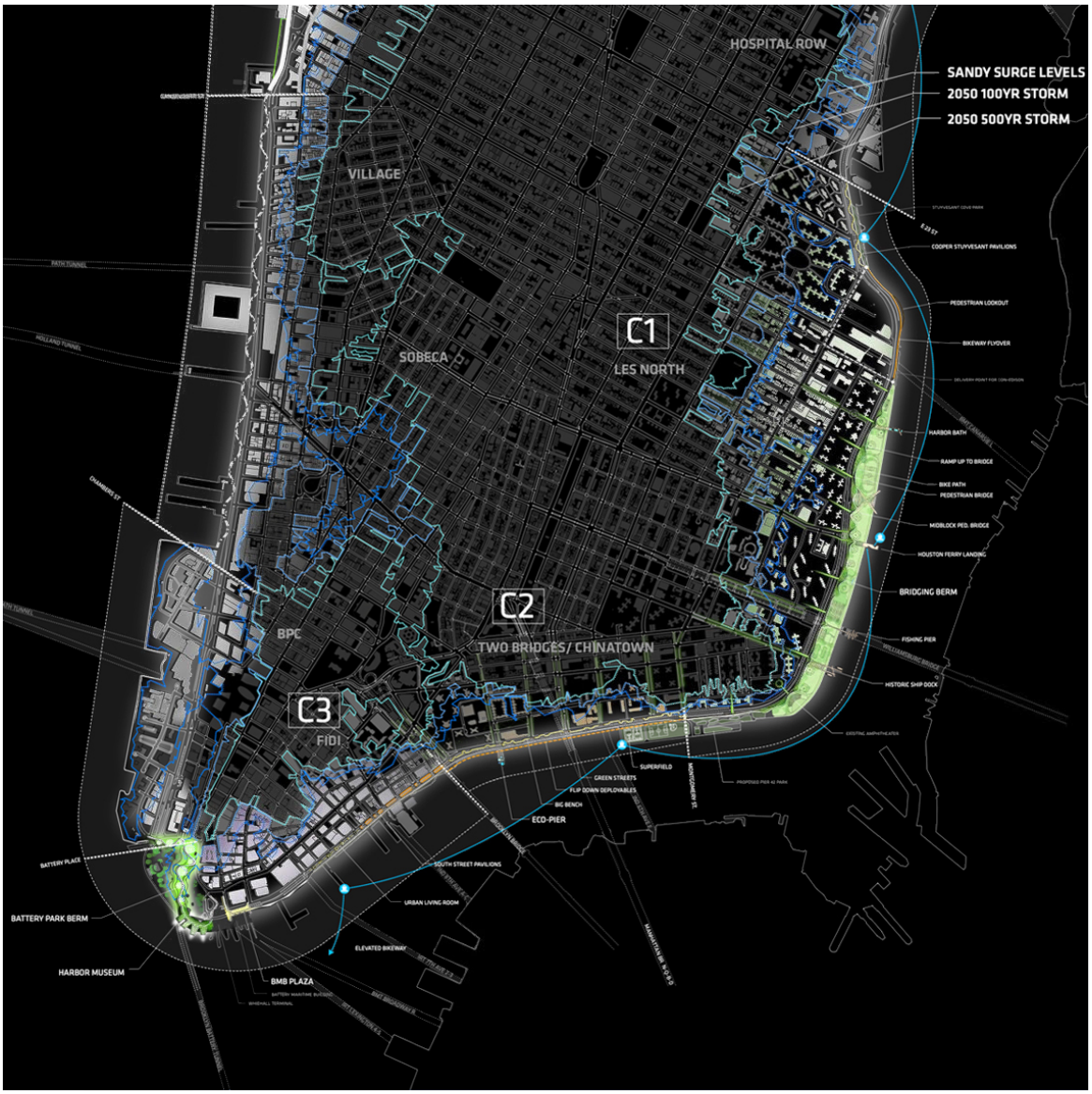

Fig.4 Different flood-risk zones are encompassing new accessibility levels in South Manhattan (2013-ongoing)

The post-Sandy focus produced several studies and initiatives that were central to the Lower Manhattan climate resilience programme, including New York's Special Initiative for Rebuilding and Resilience (SIRR), the NY Rising Community Rebuilding Programme through the Governor's Office of storm recovery, the federal Rebuild by Design competition, Mayor Bill de Blasio's One NYC Plan, informing the Southern Manhattan Coastal Protection Study. Against this backdrop, the Big U project by BIG Bjarke Ingles Group (2013 – ongoing) reimagines the southeast coast of Manhattan by rethinking a continuous public space corridor through a series of baffles in case of sea level rise. This led to the redefinition not only of the coastal defense line but of the public green infrastructure as a whole, reconsidering access points, closure systems, barriers, built spaces, amenities, public terraces and the connection system along the riverfront. From this preliminary vision phase, the city developed specific planning tools for each target areas (NYC, 2020; FIDI; Seaport, 2021). It is a territorial-scale project, re-designing a complex multi-levelled coastline over 15 km. The urban design strategy deals with three main river segments: East River Park, Two Bridges and Chinatown, Brooklyn Bridge and the Battery (Fig.4). Each compartment includes physical flood protection and hydraulic solutions which separate and isolate flash floods from the other areas: the compartments are designed as unique elements while remaining connected with one another. The project was developed with significant participation from associations and local and federal stakeholders while addressing, at the same time, new accessibility levels through walkable and cycling infrastructures along the coast. Working with local communities, in fact, brings the resilient project toward a socio-spatial definition of user-centered solution towards risk awareness and understanding of the surrounding urban environment. This is why BIG defines The Big U as "an example of what we call social infrastructure," where both flood protection components and new collective spaces are rethought in a holistic view.

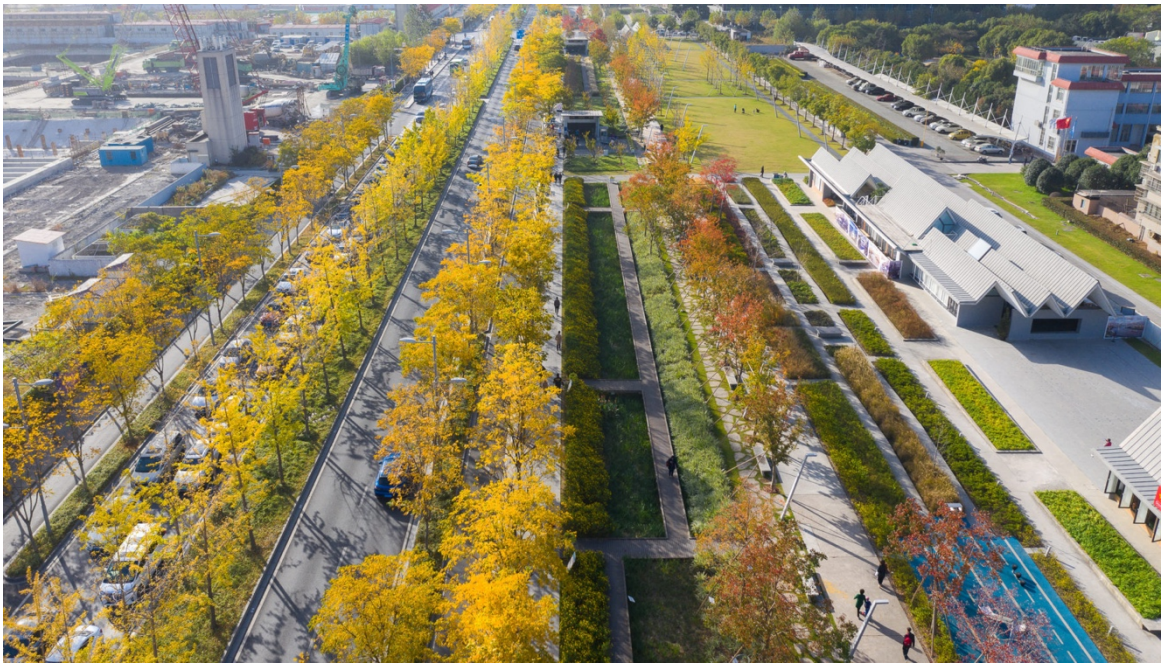

Fig.5 The new layout of Yunjin Road promotes bicycle accessibility into Xuhui Runway, Shanghai (2015-2020)

At urban scale, the Xuhui Runway Park designed by Sasaki (2015-2020) in Shanghai —located on the Yangtze River and crossed by the Huangpu River— redevelops the disused airfield at the former Shanghai Longhua Airport through a comprehensive landscape reclamation process of the whole area. The main concept is to create a core urban green infrastructure where only a pedestrian and bicycle path system can provide access, and implement stormwater management systems into the surface design (Ming-Jen, Zhang 2019). The project still preserves some portions of the former runway (Sasaki, 2020) by offering at the same time different open-

air sport programs and fostering social accessibility for people of all ages and backgrounds, through a sequence of spaces structuring linear "park rooms". The park also supports local response to flash and stormwater retention (sponge effect), which acts as an extensive blue-green infrastructure with 5.760 sq.m gardens and an 8.100 sq.m wetland along the bordering parkways (Sasaki, 2020). This is the first weather management garden built in the city of Shanghai. While runoff from the upper half of the site passes through the multiple park rooms into the main drainage channel, the southern half drains through a series of edges designed as filtering wetlands. Channels are designed mimicking natural ditches to reduce the speed of water runoff, along with wetlands that have been planted and filtered, helping to minimize the amount of suspended sediment and pollutants in the water from road surfaces. Ultimately, all the runoff from the site flows into the Jichang Canal, which then drains into the Huangpu River. The creation of the park and the addition of new bicycle pathways have facilitated the growth of inter-modal hubs connected with pivotal metro stations for the neighboring residential areas. These new pathways blend in the park structures creating connectivity layers which capillary responds to land-use organization and vegetation pattern definition (Fig.5).

2.2 Re-naturalizing ecosystems

The approach to enhancing multi-species ecosystems and increasing biodiversity (Lazzarini et al., 2024) by investigating socio-ecological structures is intertwined with developing new forms of mobility and experiencing the territory (Pinto & Fossati, 2020). Repurposing previously inaccessible spaces due to being reserved for heavy infrastructure or large urban and territorial voids left by decommissioned European industries has led to improved quality of life, connections, green spaces, and biodiversity.

Fig.6 Re-naturalization of the Emscher channel as regional bicycle infrascape at NODU Park in Duisburg (1990-2002)

The memory of places and the history of communities serve as the defining elements of the NODU project by Latz and Partner for the Duisburg Landschaftspark (1990-2002), where the disused industrial heritage of what was one of Europe's main steel ecosystems (Stilgenbauer, 2005) integrates with the reclaimed green landscape. Here the concept of green infrastructure intertwines with new cultural and leisure programmes through the reinvention of the abandoned infrastructural industrial and mining assets merging together to

create unexpected landscapes, privileged viewpoints, and new forms of slow, integrated mobility. The traces left by old railway lines, now colonized by plant life, give rise to new landscape elements such as watercourses and connection systems offering long regional hiking and bicycle trails (Fig.6). Additionally, the post-industrial nature of the region is reinforced with reclamation of high ecological value of Emsher channel, which soil and water contamination has been processually designed as a landscape reclamation machine. Today, Duisburg Park contributes to the conservation of new natural and endangered species which found here a new living habitat, through an intermediate nature of artificial and new landscape configurations. The project's connectivity layer works also at the territorial scale, including NODU park as a new green lung in a system of regional landscape parks, stretched along 250 km sequence of disused industrial landscapes and former agricultural areas. Duisburg Park generates new meanings while preserving the readable productive past of those communities, from their agricultural vocation to their conversion into a steel-producing territory. The project, through the re-naturalization of polluted sites, ensures new multi-species green ecosystems, in which humans, with their slow mobility, become a component.

Fig.7 The exaptation of the former motorway along Rio Manzanares into Madrid Rio river-park (2006-2011)

The re-design of new green connecting areas born from the desire to stitch together existing fabrics and identify processes of reclaiming natural elements within the urbanized context is the objective of the Madrid Rio project by West8 Burgos & Garrido, Porras La Casta, and Rubio & Álvarez-Sala (2006-2011). The landscape exaptation of the large road infrastructure along the riverbanks of Rio Manzanares, through the creation of underground road infrastructure, has thus allowed for the liberation of a 25-meter-wide space extending over 649 ha. After the construction of the underground tunnel, development plans for individual components of the river were created: Salón de Pinos, Avenida de Portugal, Huerta de la Partida, Jardines del Puente de Segovia, Jardines del Puente de Toledo, Jardines de la Virgen del Puerto, and Arganzuela Park. The central focus of the project is the creation of a large river-park with the planting of 30,000 trees and 110 ha of new green equipped

areas along both riversides. A collection of open-air sports grounds and public facilities are connected with 30 km of new bike lanes, 10 children's areas, 6 civic centers, a sandy beach, and a kayaking rowing centre. The park has reconnected the northern and southern metropolitan area of Madrid (West8, 2011). The project entails various connectivity layers related to multi-modal access and directions: a longitudinal underground axis that maintains a fast road crossing, and a surface slow mobility system with new bridges to allow river accessibility and the ecological connectivity with the new river park (Fig.7).

2.3 Inhabiting Infrastructure

Fig.8 The public rooftop park and The Silo in the Nordhavn area, Copenhagen (2008 – ongoing construction)

Colonizing and resizing the impact of megastructures that have characterized the expansion of cities and communication routes over the last century offers new ways to redefine urban areas previously inaccessible and improve human-scale living, starting from the rethinking and redefining the public space through new slow connections, new uses of space, and therefore new ways of inhabiting the infrastructure.

One of the ongoing projects regenerating a post-industrial fabric is the Nordhavn development in Copenhagen by Cobe (2008 - under construction). The project covers a vast area of 360 ha which results to be the largest redevelopment harbour eco-district programme in Scandinavia. 800 citizens participated in the decision-making process for public space co-design alongside policymakers, architects, landscape architects, and engineers. The project is conceived as an urban archipelago of islands connected by metro lines, local public transportation and cyclo-pedestrian trails (Cobe,2008). The space of the large port infrastructure is resized through the use of canals, generating finer-grained spaces and public amenities (Fig.8). The creation of land-sea interaction surfaces allows for gradual land reclamation and urban development over time, reintroducing marine habitats and maintaining an urban scale redesigned to human dimensions. To connect the district to city of Copenhagen, a mobility corridor called "The Green Loop" has been designed, which crosses the

archipelago and will consist of an elevated metro and a bicycle highway. It's a green infrastructure primarily devoted to urban connectivity but able to support also a green linear park development. The new urban district has been planned to follow the model of the 5-minute city, with public transportation and services available within a 5-minute walk. An interesting intervention involves the typological reinvention and reuse of the old silos and industrial buildings repurposed for new uses in the harbour area. An example of this approach is The Silo, a project for the recovery of a disused concrete tower that previously served as a grain warehouse. Inhabiting the infrastructure is also seen in the JaJa studio's multi-story car park project, which includes a public park on the building's roof, thus multiplying the land available for functions open to all. The rethinking of port elements goes so far as to imagine a hotel suite inside the engine room of a historic crane, The Krane.

Fig.9 New car-free public areas and bicycle infrastructures in the Jernbanebyen district of Copenhagen (2021 – ongoing)

The reclaiming of large disused infrastructural areas is the subject of the project at Jernbanebyen by Cobe (2021-on-going), an industrial site of the Danish national railway company DSB in central Copenhagen. The area has been a freight station and train workshop since its opening in the early 20th century, gradually expanding over the years (Bøje-Kovács et al., 2023). The urban masterplan converts the industrial function into new eco-housing concepts, introducing car-free green infrastructures and local public inter-modalities. The ecosystem service provision in the new districts is supported by 11 ha of new wooded spaces and equipped parks which balance the transformation of the site. The old warehouses and buildings, enlisted as industrial heritage, will be transformed into laboratories for creative companies and start-ups (Cobe, 2021). The transformed historic industrial buildings and railway tracks, flanked by green urban spaces, will give access to 4,500 new apartments, shops, co-working spaces, restaurants, and community services. To scale down the spaces and make them accessible for the residents, Jernbanebyen is divided into distinct smaller urban quarters, each with its own character, using the specific qualities and challenges of each place as a starting point, while a network of green urban infrastructures creates the overall public space layout (Fig.9). The inclusion of linear green corridors in the reclaimed space is a central element of the entire project alongside five types of green loops identified within the fabric: Cultural Nature, Railway Nature, Local Nature, and Infra-

Nature. The green spaces themed as Cultural Nature are three large parks that connect the district from north to south with minor green areas. The Railway Nature comprises the spaces along the railroad, creating a connection from east to west. The Local Nature areas feature several equipped grounds and open spaces—all related to the former industrial buildings— giving each individual quarter a civic meeting place. The Infra Nature areas, located in close proximity to main road connections, aim to localize the intermodal parking hubs for support the car-free programme of the district and give access to the extensive bicycle infrastructure which will connect Jernbanebyen with the southern part of Copenhagen metropolitan area (Cobe, 2021).

Fig.10 The Bentway bicycle infrastructure supports urban regeneration projects in Toronto (2016–2018)

Inhabiting the infrastructure is an urban recycling strategy which offers the opportunity to rethink the spaces beneath large mobility corridors, which often become barriers between parts of the city and inaccessible areas. The Bentway, formerly known as Project: Under Gardiner, done by Public Work Office for Urban Design and Landscape Architecture (2016-2018), is a 1.75 km cyclo-pedestrian path under the Gardiner Expressway, commissioned in partnership by the Judy and Wilmot Matthews Foundation, WATERFRONToronto, and the City of Toronto. The project has transformed the underside of the viaduct into a public space where visitors can experience a variety of activities and programs. The project connects seven Toronto neighborhoods with nearly 100.000 residents, expanding access to key attraction point of the city, such as the Fort York National Historic Site, creating a new continuous public space, by improving connectivity to the city's waterfront (Public Work, 2018). The first development phase of the Bentway project opened in January 2018 with the Skate Trail and the section next to Strachan Gate. The vision for the project includes the continuous multi-use trail for pedestrians, skaters and cyclists, a grand staircase at Strachan that doubles as seating for an urban theatre, and a series of flexible tactical urbanism approach interventions to support year-round performance and programming spaces that can be used by the community. The multifunctional space demonstrates how the recovery and reuse of existing monofunctional infrastructure can support new forms of public activities. The

initiative is focused on helping citizens to reclaim and transform this underused space towards an active common ground for events, from farmer's markets to chamber concerts, dance competitions to experimental theatre, street art festivals to kids' camps: the possibilities for this new space are endless (Fig.10).
The expressway's series of concrete support columns, called bents, create 55 civic rooms that can function together or independently to provide spaces for a wide variety of programs and events which extend over three main sections (Public Work, 2018). The ability to create multi-use and seasonal spaces is the strength of the project in reclaiming and resizing the infrastructure spaces to a community-scale use.

3. Conclusion: walking and biking challenges as (under) valued resources

Moving towards a more accessible, walkable and bicycle-friendly city model requires concrete actions. Giving consistency to the large spectrum of benefits identified in this essay would need the definition of a holistic car-free transition strategy. No single measure, whether road pricing, transit-oriented development (TOD) or limited traffic areas, will be successful in achieving sustainable mobility in cities if not coupled with an extensive and multi-fold approach to green infrastructures to support alternative (slow) mobility choices.
From the idea of greening actions that gives meaning and beauty to physical urban spaces and open spaces, the urban planning action related to sustainable mobility should address a wide range of contribution to support post-car societal transition, by bringing economic and financial returns to a wide range of stakeholders. Businesses and property owners can in fact benefit from more walkable and bicycle-friendly places. Increased footfall has been linked to higher dwell times in city centres and increased retail revenue. Together, these can have an impact on property value, especially when linked with transport hubs or nodes where massive footfall is created. Among the consequences, gentrification processes can be identified, as seen in Copenhagen. Although the city serves as a case study in promoting soft mobility, this phenomenon has been observed in neighborhoods such as Vesterbro and Nørrebro.
The creation of bike lanes and the enhancement of pedestrian infrastructure have attracted high-income investors and residents, resulting in rising property prices. In these contexts, soft mobility has improved the quality of life while simultaneously accelerating social exclusion processes for the most vulnerable populations. Within urban regeneration processes, tools for monitoring social and economic changes in neighborhoods could serve as a basis for developing social and housing policies aimed at preventing exclusion, particularly for low-income individuals and immigrant communities.
Increasing walking also has wide-ranging benefits for the public. It creates a safer and more convenient urban environment, with less car traffic, congestion and potentially fewer accidents. It can also improve air quality (through less driving) and improve health through more active lifestyles; together, these improve public health and reduce health costs. Invest in cycle-pedestrian infrastructure can also save public investments and reduce urban negative externalities, such as pollution, noise, traffic congestion, heat island effects, etc.
Therefore, to address the complexity of the recent urban mobility issues, a kaleidoscopic set of actions and policies is required, when related to spatial challenges in diversified urban contexts. While great public spaces may be formal or informal, grandiose in scale or subdued and relaxed, they all share similar qualities that give people a reason to linger, and return. Biking places are more compact, dense with mixed uses.
Streets have to be well connected with more shade from sun and rain, green spaces, trees and public spaces. And we must pay more attention to the quality of public spaces, not just providing quantity of walkable space. In the framework of the studies developed for Bicycle infrascape research project the relationship between green infrastructure, urban well-being, ecosystem service provision and public space re-design have been recognized as an influential field of investigation for spatial planning.
The public debate on these topics is supported by extensive literature where the dialectical models of the ecological city, the inclusive city and the car-free city find new convergence and a common interpretation of green infrastructures as a strategic urban and landscape design tool for the open space valorisation.

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Many shades of green: intrinsic and network properties of urban green areas

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Abstract
Urban green spaces are a vital component of public infrastructure, yet their evaluation often relies exclusively on either qualitative descriptions, aggregate metrics or basic quantitative thresholds. Thus, research frequently overlooks intrinsic attributes, spatial integration, functional accessibility, and the broader impact on urban liveability. This paper critically re-examines the legacy of Italy's urban planning standards – specifically the Ministerial Decree 1444/1968, which introduced minimum green space requirements – to assess whether the prevailing metric-based paradigm has marginalized qualitative and locational dimensions. Through a comparative case study of three mid-sized Tuscan cities – Pisa, Lucca, and Grosseto – this research develops and applies an original methodology that integrates both intrinsic characteristics (typological, geometric, and structural) and extrinsic features (accessibility and configurational properties) of urban green spaces. Drawing on field surveys, spatial analysis, and Space Syntax techniques, the study constructs a composite evaluative framework to assess the actual usability and functional performance of green areas within the urban context. Findings reveal that a substantial proportion of green spaces are either residual or inaccessible, and are often poorly connected to the urban fabric despite formal compliance with legal standards. While national planning requirements have increased the quantity of public green space, these areas are frequently located on the urban periphery or insufficiently integrated into movement networks, thereby limiting their effectiveness. The proposed approach offers a lightweight yet robust tool for quali-quantitative assessment, enabling more nuanced evaluations and supporting context-sensitive planning practices. The study advocates for a renewed emphasis on design quality and locational integration in green infrastructure policies to enhance the equity, usability, and liveability of urban environments.

Keywords
Green public areas; Accessibility; Space syntax; Quantitative assessment; Composite Index

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1. Introduction

A few years ago, when interviewed on the topic of territorial facilities, Edoardo Salzano recalled the two etymological roots of the term "standard", assuming curiously different meanings: one referring to a model, a minimum reference value, a mandatory requirement, a performance threshold; and the other, etymologically more immediate (from the French *estandart*), meaning a banner, a flag.

It is undeniable that in 1967, the Italian law 765, and the following year, the ministerial decree 1444, made these two meanings to overlap and align: the legal recognition of the right to territorial provisions of a predetermined and non-negotiable minimum amount, as something to be celebrated by proudly raising a flag on a difficult yet victorious battlefield.

However, more than fifty years after the introduction of urban planning standards, it is equally undeniable – as Salzano himself, along with several other urban planners, acknowledged – that the pride evoked by the second meaning quickly faded, giving way to the accounting practice for which the first meaning – a minimum numerical reference – has commonly become both an expression and an operational tool.

Among territorial provisions, public green spaces are the most prominent – not only because of the minimum extension granted to them in 1968, but above all due to the significance of the values they symbolically represent. Unlike spaces for parking, education, and activities of common interest, public green areas do not merely serve functional needs; they also embody elements of nature within the urban environment, recognized as an indispensable resource for the community. These spaces fulfil a variety of roles, spanning ecological-environmental, social and recreational, cultural, and hygienic-health purposes.

For these reasons, the planning of public green areas was a central subject in 20th-century urban planning and design manuals, where it was widely and extensively addressed, accompanied by a detailed set of technical guidelines and design recommendations.

Enrico Tedeschi's essay (1947), published by Metron in the immediate post-war period, provides a clear example: it offers highly detailed technical guidelines for collective services, categorized into various types, outlining their dimensions, location in relation to residential areas, and influence based on settlement density. A similarly meticulous focus on the topic can be found in later manuals, from Piccinato (1947) to Rigotti (1947), and from Dodi (1953) to the Manuale dell'Architetto (CNR, 1946), across its different post-war editions. It is difficult to find such an extensive discussion and analysis on the subject in the late 20th and early 21st centuries.

All this highlights how sensitivity and attention to the issue of urban green spaces – both in terms of their intrinsic characteristics and their location – were widely shared and deeply rooted in the early years of post-war urban expansion. Paradoxically, however, this attention waned when, in 1967, a minimum provision of public green space was legally established, and the following year, this provision was strictly quantified across the different homogeneous zones into which municipal territory was divided.

In other words, the legal recognition of public green space as an inalienable and non-negotiable right for every resident – a glorious achievement marked by the banner of Law 765 – paradoxically seems to have diminished interest in the intrinsic nature of this provision and its specific locational characteristics. It is as if the cultural and political struggle to secure the right to green spaces (and other public services, of course) had absorbed all attention, diverting focus away from the design solutions necessary for their actual implementation in terms of structure and location. Once the political and legislative victory had been achieved, much of this attention seemingly evaporated: all guidance on the creation of public green areas became encompassed within and absorbed by the definition of the minimum standard, an unavoidable threshold whose fulfilment came to represent the entirety of the issue.

It is perhaps even more surprising how this attention has remained weak and marginal, even when, starting from the 1980s, the inadequacy of urban planning standards as a factor and guarantee of settlement quality

became evident, sparking a lively debate on ways to move beyond them – a debate that, despite its breadth, has largely remained unproductive.

Indeed, while over half a century of experience has clearly shown that the issue of territorial provisions – and urban green spaces in particular – has been reduced in practice to mere compliance with an accounting obligation, amounting to nothing more than a simplistic numerical verification, discussion and testing of alternative strategies for ensuring an adequate provision of public green spaces in urban areas are still on going. Beyond addressing entirely heterogeneous needs and aspects, ranging from the ideas of green city, healthy city to ecosystem services, which struggle to be synthesized into a single integrated approach, the fundamental issue remains unresolved: how to translate the control of these aspects into rigorous procedures – ideally objective and, if possible, not overly complex – so that they can be easily applied in planning practice. These very qualities – perhaps the only ones – that the Legge Ponte standards certainly did not lack are precisely what ensured their primacy for over half a century of widespread and consistent use.

In such a context of persistent uncertainty, it becomes particularly relevant to examine a diverse sample of Italian urban settlements in order to analyse the intrinsic characteristics of public green spaces and their configurational properties, with special attention to those created after the introduction of regulations on standards. The discussion of the results of this exploration will allow assessing the actual suitability of green areas for the various needs they are intended to serve and, conversely, the effectiveness of law 765 in meeting the requirements for green spaces aimed at social and recreational, cultural and health-related purposes for which it was enacted.

To reach these result, three subgoals are stated: (a) analyse the amount and the intrinsic characteristics of green spaces within the city; (b) analyse the extrinsic characteristics of the green spaces, with a particular focus to their accessibility; (c) discuss the overall suitability of green public spaces by combining intrinsic and extrinsic features, proposing a lightweight analytical tool designed for preliminary but effective quali-quantitative assessment – going beyond the simplistic use of general or aggregated values. The case studies analysed in this paper are the three historical Italian settlements of Pisa, Lucca and Grosseto, selected because of their demographic size, quite similar, which enables a reliable comparison of the results.

In this vein, the paper is structured as follows. Section 2 provides a background about studies analysing the impact of green areas features on liveability, especially focused on quantitative approaches. Section 3 presents the three case study areas – Pisa, Lucca and Grosseto, in Tuscany (Italy) – by briefly discussing their main characteristics from a morphological, demographic and historical perspectives. Section 4 illustrates the datasets and methods employed. Section 5 presents the results and their discussion, providing interpretative tools and cutting-edge infographics to assess the overall suitability of green public spaces. Finally, Section 6 provides the general conclusions.

2. Background

Urban green spaces are a central concern in contemporary urban planning, as they significantly influence both the psychophysical well-being of residents and the environmental resilience of cities (Li et al., 2005). Numerous studies have demonstrated how the presence of green areas contributes to stress reduction, increased physical activity, and social cohesion, as well as to the mitigation of climate change effects, such as urban heat islands and hydrogeological risks (Biernacka & Kronenberg, 2018). Urban greenery is thus not merely an aesthetic or recreational resource, but a vital ecological and social infrastructure (Mihinjac & Saville, 2019). In fact, the value of green spaces extends beyond their physical and ecological characteristics to include perceived and symbolic dimensions, such as visual quality, sense of safety, mental well-being, and the urban identity they help to construct (Zhang et al., 2021). This symbolic and functional diversity is further confirmed by recent research highlighting the spatial heterogeneity of green space values across cities (Giannakidou &

Latinopoulos, 2023), and the varying capacity of green spaces to support biodiversity and ecosystem services depending on local planning approaches (Lazzarini et al., 2024).

Over time, methodological approaches to urban green space analysis have evolved. Traditional qualitative perspectives have been increasingly complemented by quantitative methods aimed at supporting qualitative analysis and developing composite indicators to capture the many characteristics, multifunctionality, and impacts of green spaces. As discussed by Haaland & van den Bosch (2015), the increasing adoption of the compact city model – driven by rising urbanization trends over recent decades and reinforced by the concrete and inevitable projections for the future (UN Habitat, 2022) – underscores the need to develop multidimensional assessments of the impact of green infrastructures, including from an environmental perspective, given the ongoing climate crisis and the need for systemic adaptation strategies (Ceci et al., 2023; Isola et al., 2024).

Among these multidimensional assessments, green types have been defined (for a review, see Kabisch et al., 2015), and several significant indicators have been developed, including tree canopy coverage (Nowak and Greenfield, 2012), biodiversity (Aronson et al., 2017), and proximity (Rigolon, 2016).

Accessibility, overall, has emerged as a relevant dimension in assessing green space performance. It must be understood not only as the physical ability to enter a green space – sometimes limited by physical, social, or cultural barriers (Pantaloni et al., 2024; Bocca, 2023; Wolch et al., 2014) – but also in terms of its strategic spatial location within the urban fabric, known as, in configurational terms, spatial centrality (Hillier, 2007), which can be used to determine whether the green spaces are easily connected within the urban grid (pathways, cycleways, or road network) or not.

In this regard, Space Syntax has proven to be an effective methodology for analysing the spatial structure of cities and revealing the integration and connectivity potential of green spaces. Several contributions (Hillier, 2007; Karimi, 2012; Cutini, 2016) have shown how syntactic measures – such as integration, choice, and depth – offer a novel perspective on the legibility, accessibility, and attractiveness of open spaces, moving beyond simple physical distance metrics.

More than this, recent applications of Space Syntax in the study of green areas have further expanded its relevance in this field, showing its correlation with some actual and perceived phenomena. Tannous et al (2021) showed how urban planning can strongly influence accessibility, highlighting how large parks often follow spatial logics aligned with integration patterns – given their proper planning process – while smaller ones tend to emerge from irregular land availability, weakening spatial coherence and their accessibility. Moreover, studies have confirmed that green spaces with higher syntactic integration are not only objectively more accessible but are also perceived as such by users, reinforcing the connection between spatial form and lived experience (Gomaa et al 2024), fostering as a consequence social interaction. In a similar manner, accessibility and spatial configuration impact on perceived security, with low visibility and poor connectivity resulting in risky perception of green areas (Farkhondeh et al., 2023), once again highlighting the connection between form, position, access, and liveability, and thus proving Space Syntax ability to enhance spatial equity (Wang et al., 2022).

Finally, Space Syntax proved an useful tool not only in extracting intrinsic characteristics of urban spaces or in helping to discover hidden correlations, but also in identifying and addressing inequities in green space accessibility among different social groups (Huang et al., 2023), and to propose interventions for improving the usability and attractiveness of campus green spaces (Li et al., 2019). Collectively, these studies illustrate the versatility of Space Syntax as both an analytical and a design-support tool for rethinking urban greenery as a structurally integrated, socially inclusive, and perceptually meaningful component of the urban fabric.

Building on these insights, this paper proposes an integrated approach that encompasses both the intrinsic characteristics of green spaces – such as typology, form, dimension, barriers – and their extrinsic dimensions – such as accessibility, centrality, and localization. The aim is, as stated in the introduction, to offer a

multidimensional framework for the quali-quantitative analysis of urban greenery, going beyond simple and aggregated quantitative analysis, thus exploring the "many shades of green".

3. Case studies

This study examines three cities located within Tuscany, Italy: Pisa, Lucca, and Grosseto. These all are three historically founded urban centres in Tuscany, each with comparable population sizes – approximately 90,000 inhabitants in Pisa and Lucca, and around 80,000 in Grosseto. Despite these demographic similarities and a shared process of modern suburban expansion radiating from historically walled cores, these urban areas differ in terms of historical development, urban morphology, and spatial characteristics, providing diverse contexts for analysing urban quality and accessibility of public spaces and thus allowing the exploration of green public areas dynamics and the identification of potential trends among the three case studies.

All three historic centres are densely built and enclosed by preserved – or partially preserved, in the case of Pisa – fortification walls. However, the physical dimensions of these cores differ: Pisa and Lucca possess similarly sized historic centres (approximately 2 km^2), while Grosseto's is comparatively smaller (approximately 0.3 km^2). The character and role of the city walls also vary: in Lucca and Grosseto, the walls are walkable and integrated into green infrastructure, whereas in Pisa, they function primarily as a boundary element, although they adjoin the unique green space of Piazza dei Miracoli – one of the largest open areas within the city.

The relationship between each city and its river system further illustrates morphological divergence. In Pisa, the Arno River serves as a central yet divisive element in the urban fabric. In Lucca, the Serchio river lies at the periphery, marking the edge of suburban development. Grosseto, lacking a river within the city itself, is nevertheless marked by the presence of a pre-existing reclamation canal, later covered over, whose area significantly constrained urban expansion, particularly regarding green spaces, since the culverting has, in fact, created a wide opportunity for their development.

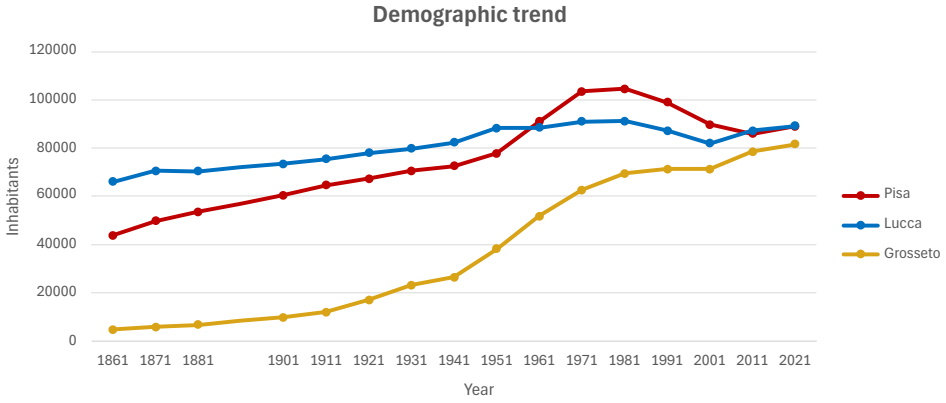


Fig.1 Demographic trends in Pisa, Lucca, and Grosseto from 1861 to 2021.

Patterns of suburban growth also differ markedly. Lucca has developed according to a radial and somewhat organic mode, while Grosseto and Pisa's development was addressed by the planning strategies of two master plans by Luigi Piccinato: predominantly northward along a defined infrastructural axis Grosseto, primarily toward the east Pisa. It is worth noting that, despite the current similar size of the three cities, a marked difference distinguishes the recent urban development of Grosseto from that of Lucca and Pisa – one that also has implications for the current provision of green spaces. For historical reasons, Grosseto underwent significantly greater physical and demographic growth throughout the twentieth century compared to the other Tuscan cities (see Fig.1), resulting in a settlement that is, for the most part, of recent (or very recent) origin. Furthermore, this development followed a compact urban pattern with relatively high density, setting it apart

particularly from the expansion of Lucca, which in recent decades has experienced low-density sprawl, largely devoid of public spaces within it.

Based on this contextual understanding, the boundaries of the study areas for spatial analysis were delineated to include both the historic centres and the adjacent suburban zones extending to the edge of the first rural belt, as Fig.2 shows. This delineation was guided by the continuity of the built environment rather than by a priori standardized area sizes. As a result, the study areas encompass approximately 20.8 km^2 in Pisa, 14.7 km^2 in Lucca, and 13.3 km^2 in Grosseto.

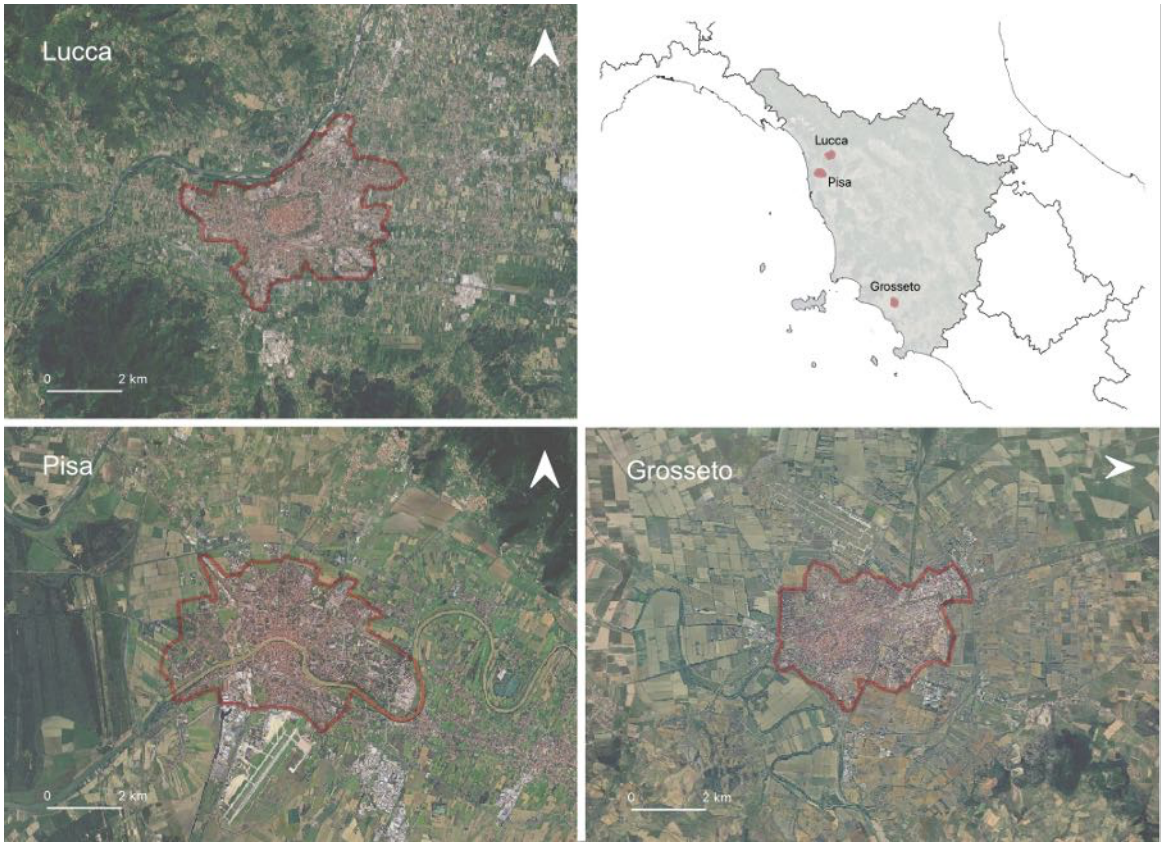


Fig.2 General overview of the case studies: location and geographical extent of Lucca, Pisa, and Grosseto (Tuscany, Italy).

4. Datasets and methods

To assess public green areas intrinsic and extrinsic characteristics, three primary datasets were employed.

First, the Regional Cartography (CTR 2k Regione Toscana), which served as the spatial reference layer for all analyses conducted. It provided a detailed cartographic base onto which the collected data through the on-field survey of (a) Green Areas, (b) Access Points, and (c) Urban Cycle Paths were digitized and spatially integrated.

Second, the OpenStreetMap (OSM, 2025) road data. Following extraction, the dataset underwent a process of categorization and data cleaning to ensure accuracy and consistency. Specifically, road segments with an *fclass* value corresponding to the following categories were retained: "living_street", "motorway", "motorway_link", "primary", "primary_link", "residential", "secondary", "secondary_link", "tertiary", "tertiary_link", "trunk", "trunk_link", "service", "cycleway", "footway", "pedestrian", "steps", "track". From this dataset, Normalised Angular Choice (NACH) values at two different radii (Rn and R800m) were calculated in the software DepthmapX in accordance with Space Syntax theory (Hillier 2007; Turner 2007; Cutini 2016). These values offer insights into the movement potential and accessibility patterns of urban spaces, aiding in

the assessment of the positional values of green areas and the intrinsic relation with the urban fabric, as detailed in Section 5.

Third, the Orthophoto Cartographic from the *Istituto Geografico Militare* (OFC 1965 IGM-RT, OFC 1975-76 IGM-RT), downloaded from the Geoscopio Toscana (Regione Toscana, 2019), and Piccinato Urban Plans have been used to add a diachronic analysis of the green public areas. The following paragraph details the collected data and how the georeferenced dataset of green areas has been elaborated.

4.1 Survey and data collection methodology

The dataset of green areas, access points, and urban cycle paths have been created from scratch for this research. In particular, three subsets were created: a polygonal layer comprehending the urban green areas, a point layer containing the access to the gated urban public areas, and a linear layer representing the cycle paths. For each subset, a comprehensive set of attributes was recorded, then integrated within one single polygonal layer through GIS spatial tools. Several parameters were selected to comprehensively represent the actual qualities of the current urban green areas. As mentioned above, those parameters can be distinguished in intrinsic features, inherent to the local, geometric and functional aspects of each area, and its locational characteristics, or extrinsic features, referring to the relationships with its surroundings and the whole settlement as well. The final parameters are listed and described here below, and summarized in both Fig.3 and Tab.1, with the first one focusing on the methodological framework and the second one on the specific attributes included within the final georeferenced dataset of green areas. Green public areas were thus identified and georeferenced with the following fields:

- ID code: unique identification code, for each polygon, with the information about the municipality where it is located and a progressive counting, in the format *MUN_nnn*;
- Year: whether the green public space was already in place before the 1968 or not [ante 1968; post 1968];
- Class: the type of green public space, depending on its use [Park/Public Garden; Equipped; Sporting; Associated with other services; Traffic-enclosed (e.g., median strips, roundabouts, railway-adjacent greenery), which is non-accessible; Residual; Other];
- Area: the dimension of the green area, expressed in square metres;
- Compactness: the ratio between the area and the square perimeter, expressed by the formula $C = 4\pi \mathrm{A} / \Pi^2$, inspired by the Visibility Graph Analysis Isovist Compactness metric. It has the ability to estimate how compact (close to a circle) a shape is;
- Gated: whether the public green area is fenced or not [yes; no];
- Public accessibility: the physical accessibility to the green public space, whether it is open, closed, or restricted in some periods or subject to the payment of a fee [free; limited (in time or under payment); inaccessible];
- Local centrality: the positional value – according to the configurational concept of centrality – of the green area within the urban environment in a logic of pedestrian movement, calculated using NACH 800m, with R=800m meaning the walking distance of an elderly person in 15 minutes;
- Global centrality: the positional value in a logic of vehicular movement, calculated using NACH Rn (Van Nes and Yamu, 2021);
- Cycleways: whether a cycleway serves the public green space or not [yes; no];
- Parking: whether a parking is present nearby, within a radius of 50 metres [yes; no].

Please note that all the fields were automatically detected within the on-field survey, then obtained in their final form just by combining the punctual, linear and polygonal layers information. The only exceptions are

represented by the year information, retrieved from the OFC 1965 IGM-RT, OFC 1975-76 IGM-RT (Regione Toscana, 2019) and urban plan of Piccinato for Pisa and Grosseto – from which it was possible to distinguish green public areas already present from those not yet realized through cartographic overlapping and critical analysis in a GIS environment – and the centrality fields, which required the association of NACH measures to the public green areas. In particular, once calculated the Space Syntax metrics (NACH Rn and NACH R800, weighted by length according to Turner 2007) on the municipal areas, the value of the highest-integrated street facing the green area has been associated to it.

This choice was made to retain the strongest configurational affordance of each space and avoid potential distortions that could arise from averaging surrounding values, especially in cases where highly integrated segments are flanked by poorly integrated ones. For fenced green areas, the closest street segment to the actual access point has been considered.

This method permitted the association of both global and local measure of configurational accessibility to each public green area. Once the aforementioned dataset was constructed, a cross-spatial analysis was conducted integrating the various collected parameters, in order to perform a quali-quantitative assessment of urban greenery across the three case studies.

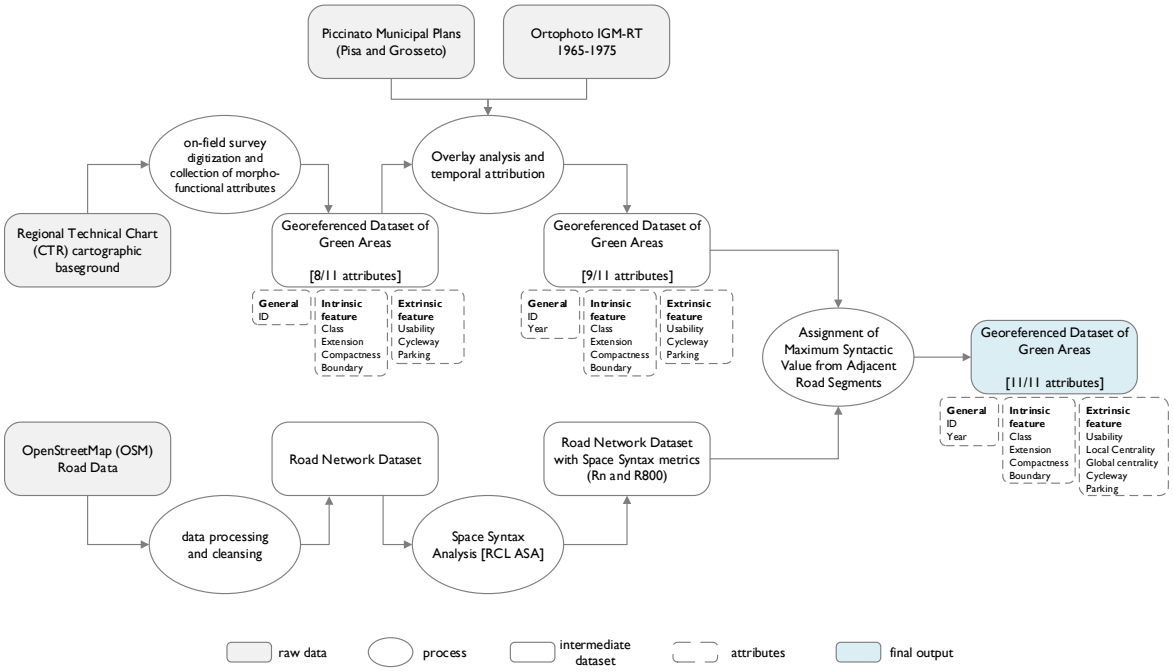


Fig.3 Methodological workflow of the research.

General info		Intrinsic features				Extrinsic features				
MUN_ID	Year	Class	Extension	Compactness	Boundary	Usability	Local centrality	Global centrality	Cycleways	Parking
PI_xxx LU_yyy GR_zzz	Pre 1968 Post 1968	Park/Public garden Equipped Sporting Assoc w services Traffic-enclosed Residual Other	Value [sqm]	Value	Yes No	Free Limited Inaccessible	Value NACH R800	Value NACH Rn	Yes No	Yes No

Tab.1 Summary of the parameters included in the georeferenced dataset of green areas, grouped in General Information (ID, Year), Intrinsic Features (Class, Extension, Compactness, Boundary) and Extrinsic Features (Usability, Local centrality, Global Centrality, Cycleways, Parking).

5. Results and Discussion

Following data processing, quantitative analyses of urban green spaces were conducted, structured – as already said – around a tripartite discussion: intrinsic features, extrinsic features, and an integrated assessment of both, with the ultimate aim of evaluating the effective suitability of urban greenery, highlighting somehow the distinction between quantity and quality. The three selected case studies thus provide a common baseline for a comparative analysis of how intrinsic urban characteristics – such as specific land use, surface area, and spatial form – and extrinsic elements – such as levels of public accessibility and transportation infrastructure – contribute to urban environmental value.

Given the similar structural origins of Pisa, Lucca, and Grosseto – with, as this section will highlight, quite different outcomes among them – it becomes particularly meaningful to investigate not only the total amount of urban green space, but also its typology, spatial distribution, and accessibility. This enables a more comprehensive and quantitative assessment of green infrastructure that moves beyond a purely numerical or superficial approach, which – as the analysis will show – can often be misleading or devoid of real significance. Emerging trends have been synthesized into summary infographics, designed to facilitate immediate visual comparison among the three case studies, thereby enhancing both accessibility and interpretability of the findings.

5.1 Intrinsic features

The analysis of intrinsic features provides a geometrical-functional characterization of urban green areas, offering insights into their spatial distribution and, to a limited extent, their diachronic evolution – specifically between the pre- and post-1968 periods. These data are summarized in Fig.4, which presents a spatial comparison of green spaces distribution and morphological characteristics across the three case studies on the left side – categorized by class – and, on the right side, a set of diagrams for each case. These include a quantitative distribution diagram by class, and four bar charts reporting on geometric attributes (extent and compactness), the presence of fencing, and the year of establishment. All charts present values as percentages of total green space surface, rather than by number of individual green areas, in order to provide a more meaningful and quantifiable metric that avoids misleading interpretations due to fragmentation or size variance.

In absolute terms, the total surface area of urban green space is relatively comparable across the three cities: 2.45 km² in Pisa, 2.16 km² in Lucca, and 2.87 km² in Grosseto. However, their spatial distribution patterns reveal distinct differences. In Pisa, green areas are more fragmented and dispersed across the urban fabric. In Lucca, they are more clustered – most notably around the historic city wall park, which stands apart as a prominent and singular green landmark. In contrast, Grosseto presents a more zone-based and visually cohesive distribution, with green areas appearing as integral parts of residential neighbourhoods, even though internally composed of smaller, discrete units.

From a typological standpoint, the classification of green spaces by class reveals notable trends across the three case studies. A striking observation is the substantial presence of residual green areas in all three cities, accounting for 30% in Pisa, 15% in Lucca, and 22% in Grosseto – representing, respectively, the first, third, and second highest values within each city's typology profile. Conversely, the most "valuable" types of green space – parks/public gardens and equipped green areas – constitute nearly half of the total green public space in Lucca (49%), 45% in Grosseto, but only 30% in Pisa.

Although the relative proportion of small-scale green spaces (i.e., those smaller than 200 m²) remains fairly limited – accounting for 4% in Pisa, 3% in Lucca, and 2% in Grosseto – Grosseto exhibits the largest average green area size, suggesting a more deliberate and consolidated pattern of land allocation for greenery. This impression is further supported by Grosseto's high compactness index, with over 90% of green areas scoring above 0.12, and the predominance of the park/public garden typology, which represents 38% of the city's

green space stock. This contrasts sharply with Pisa, where the same category accounts for only 24%.

Fig.4 Intrinsic features representation in the three case studies and infographics on the specific features.

Temporal distribution patterns reinforce these distinctions. Grosseto exhibits a more recent green space development trajectory, consistent with the demographic and urban growth discussed earlier: 84% of its public

green areas were established after 1968, compared to 49% in Pisa and 43% in Lucca. This suggests a more modern and possibly master-planned green infrastructure strategy in Grosseto, aligned with its urban expansion phases.

In general, spatial compactness confirms the greater fragmentation of Pisa and Lucca compared to Grosseto, based on data related to the urban form of green spaces. In Grosseto, green areas tend to be more geometrically regular, followed by Pisa (80%) and Lucca (76%). These differences reflect not only morphological characteristics but also potentially divergent planning approaches. While compactness is undoubtedly a rough metric, it still enables the identification of green spaces that, due to their irregular geometric configurations, are functionally inadequate as recreational or social environments. These often correspond to residual spaces – byproducts of other land uses – particularly marginal areas adjacent to vehicular infrastructure.

The analysis of enclosure conditions further reveals that approximately one in four public green spaces is gated. This is a significant factor affecting also accessibility, as these areas often impose temporal or group-based access restrictions – or both – thereby reducing the proportion of green spaces that are effectively usable by the public.

A particularly insightful aspect of the analysis is the relationship between green space typology and year of establishment. As shown in Fig.5, a network-based representation captures both the temporal evolution and the spatial clustering of recently developed green areas. These patterns are further clarified in Fig.4, which synthesizes the typological shifts across time periods using a radar chart. Notably, Pisa is the only city in which the three categories with the highest percentage increases are all medium-to-high qualitative types: sporting areas (+554.7%), parks/public gardens (+205.7%), and equipped green spaces (+139.1%). In contrast, Lucca shows the highest increase in sporting areas (+294%), followed by green spaces associated with services (+114%) and residual green (+94%). Interestingly, the smallest increase in Lucca is in the park/public garden category (+48%), which nonetheless still represents a substantial portion (approximately 46%) of the city's current green public areas – largely due to the historical city wall park. Conversely, Grosseto shows its three highest percentage increases in equipped green spaces (+2172%), residual green areas (+1725%), and traffic-enclosed green (+570%). This pattern reflects the city's extensive urban expansion after 1968, which resulted in a considerable growth in public green areas. However, this growth was driven by lower-quality green space typologies, despite the overall substantial increase across all categories.

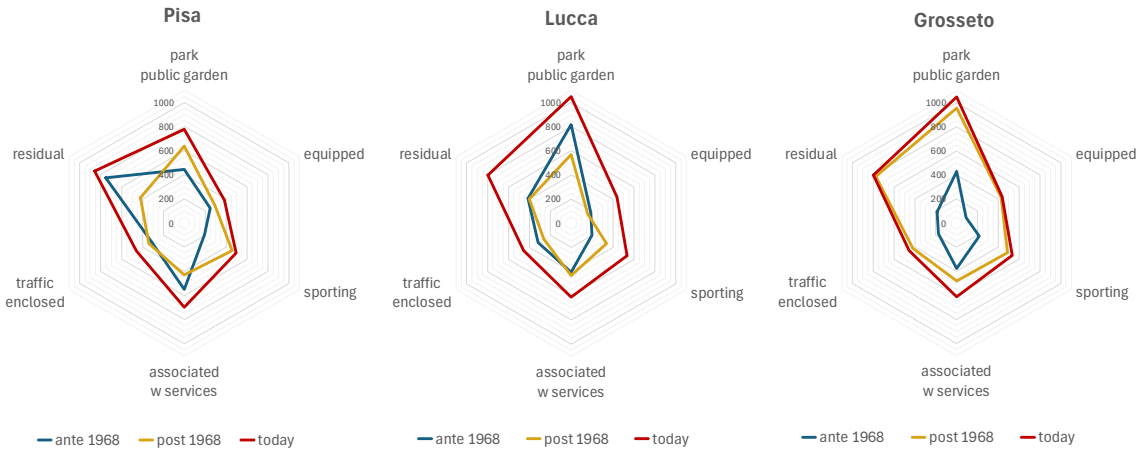


Fig.5 Radar charts comparing the class proportions of the three case studies [square root of the amount] before 1968, after 1968, and across the entire period.

Ultimately, this multidimensional examination of the intrinsic characteristics of public green spaces offers a far more nuanced and informative perspective than conventional aggregated quantitative assessments – such as

those commonly featured in planning reports or statistical yearbooks. By incorporating considerations of form, function, and temporal layering within the urban fabric, the analysis provides deeper insights. Nonetheless, one critical dimension remains underexplored: the accessibility of public green areas. This factor fundamentally shapes, in a cascading manner, the overall suitability of green spaces – understood here as their actual value in contributing to urban liveability and explored in the following sections.

5.2 Extrinsic features

The analysis of extrinsic features focuses on characteristics external to the green spaces themselves – specifically, those dependent on the surrounding urban systems and external conditions. In particular, the study emphasizes usability and spatial accessibility, including pedestrian, vehicular, and cycling access.

As discussed in Section 2, accessibility is often overlooked in green space assessments, despite its significant role in determining the actual impact of urban greenery. Extensive green areas located at the urban periphery may offer far less contribution to everyday well-being, air quality, or liveability than a centrally located urban park that is easily reachable by large portions of the population. The findings are summarized in Fig.6, which is organized into two main parts.

On the left, a spatialized comparison of green areas across the three case studies is presented, with each area categorized by usability, understood here as the type of public access. In the background, the road network is hierarchized based on spatial centrality. Red segments represent streets with high local centrality (top 20% of Normalized Angular Choice, NACH, at radius R800); yellow segments indicate streets with high global centrality (top 20% of NACH at global radius Rn); grey segments correspond to segregated parts of the network that do not fall within either category. Finally, dashed green lines represent existing bicycle lanes.

On the right, a series of bar charts present quantitative indicators – expressed as percentages of total green surface – regarding: public usability levels; centrality class (local/global/segregated); presence of bicycle infrastructure nearby; and availability of dedicated parking facilities.

A brief methodological note is warranted on how centrality and accessibility data were processed. The goal was to produce a clear and legible visualization that captured the configurational accessibility of individual urban green areas and offered a more nuanced evaluation of their extrinsic features. This classification was developed through the construction of a unified Centrality Index, derived from Space Syntax analysis, enabling the synthesis of multiple dimensions of spatial integration into a single accessibility metric. Based on this index, three levels of centrality were defined:

- Locally Central: green spaces associated with the top 20% of road segments in terms of Normalized Angular Choice (NACH) at a local radius (R800), indicative of high pedestrian accessibility;
- Globally Central: green spaces associated with the top 20% of segments based on NACH at a global radius (Rn), reflecting broader vehicular accessibility and spatial integration;
- Segregated: green areas associated with street segments that do not fall into either of the previous categories, characterized by low configurational accessibility.

This classification provides a foundation for the subsequent qualitative analyses of green space actual suitability, discussed in the following section, and serves as a key interpretive layer for assessing the broader urban performance of green infrastructures.

Fig.6 offers an overview of green space accessibility, addressing the often-overlooked dimension of extrinsic features – the external conditions that determine how green spaces are experienced and used.

Beginning with physical accessibility, the data show that in all three cities, at least 30% of green spaces are subject to access restrictions, with Pisa reaching the highest value of 39%. This category includes museum parks and privately managed sports facilities, as well as green areas linked to public or institutional services, just to give a few examples.

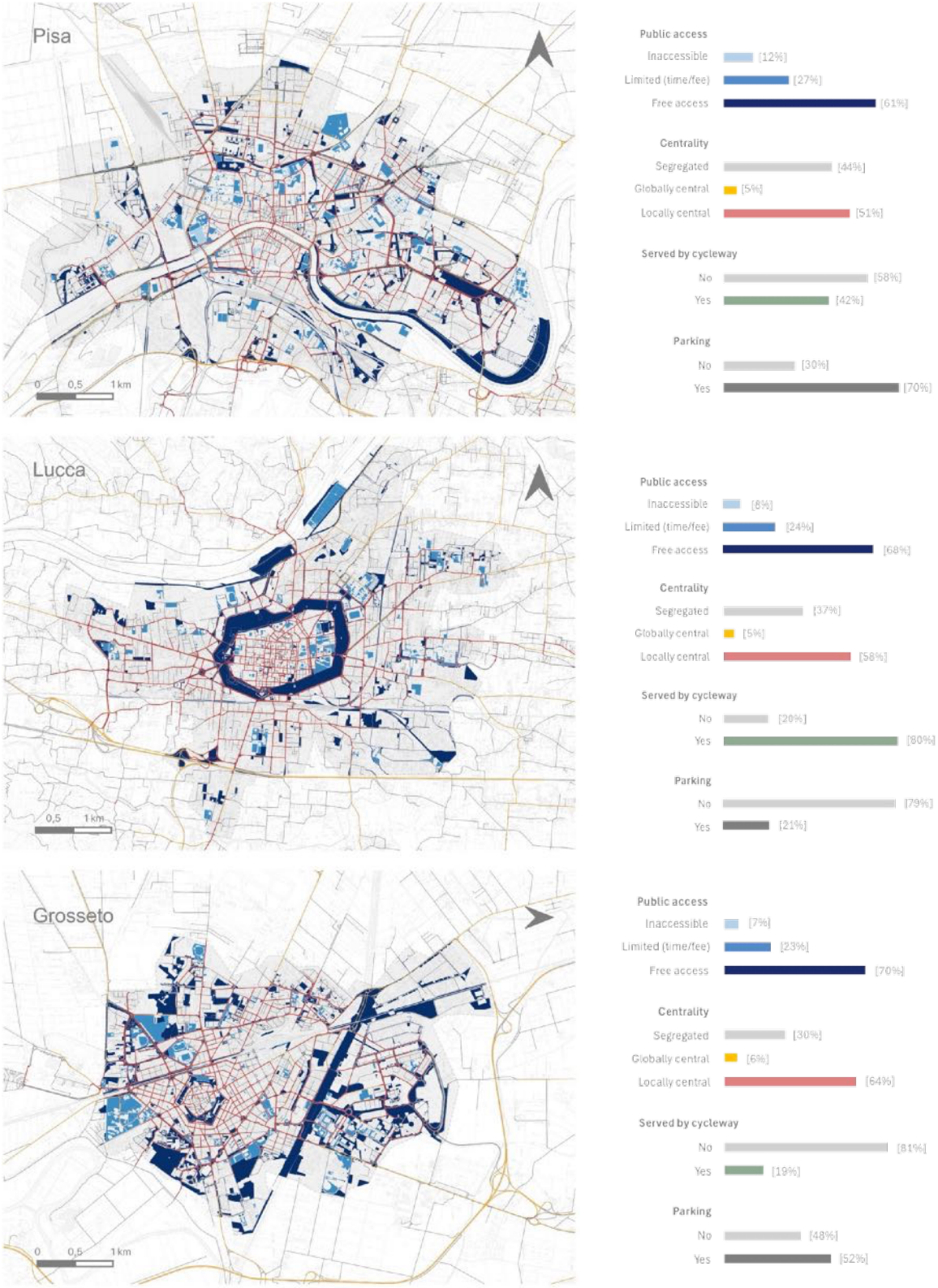


Fig.6 Extrinsic features representation in the three case studies and infographics on the specific features.

Also included are public green areas that are currently inaccessible due to construction, renovation, or neglect. However, the most common contributors to inaccessibility are traffic-enclosed green areas – spaces embedded within or surrounded by road infrastructure.

While such areas may serve ecological or aesthetic functions, they are functionally unusable by the population, despite being counted as public green space. Specifically, the share of completely inaccessible public green areas amounts to 12% in Pisa, 8% in Lucca, and 7% in Grosseto.

However, accessibility extends beyond direct physical access to include what may be termed spatial or relational accessibility – that is, the centrality of green areas both locally (in terms of walkability and proximity to residential areas) and globally (in terms of connection to major vehicular flows). The spatial configuration analysis reveals that a significant portion of green spaces is located in areas with low local centrality – 49% in Pisa, 42% in Lucca, and 36% in Grosseto – often as a consequence of high-density urban areas where space for green infrastructure is either unavailable or deprioritized. Furthermore, considering the results, even when green areas were developed in peripheral zones, little consideration was given to their integration with major vehicular flows. As a result, these spaces are often situated in low-visibility, low-accessibility locations, requiring intentional effort from users to reach them, rather than emerging as natural components of daily urban routines. This lack of integration is further supported by the high proportion of segregated green areas, as measured by configurational analysis indices. Specifically, 44% of green areas in Pisa, 37% in Lucca, and 30% in Grosseto are not located along routes with high local or global betweenness – meaning they do not even lie along commonly used paths or strategic urban connectors.

A notable exception is Lucca, where 80% of green spaces are served however by cycling infrastructure, largely due to the strategic role of the city wall circuit. In contrast, the corresponding figures are significantly lower in Pisa (42%) and Grosseto (19%), contributing further to the spatial detachment – and functional disconnection – of green spaces from the everyday lives of residents.

Altogether, these findings provide a radically different perspective on urban greenery. They underscore the importance of integrating the intrinsic characteristics of green spaces, previously discussed, with their extrinsic conditions to form a more holistic assessment. The following section presents an integrated evaluation framework aimed at discussing the overall suitability – and, in terms of urban liveability, the functional value – of public green areas.

5.3 Integrated assessment

In addition to the separate evaluation of intrinsic and extrinsic characteristics, and the corresponding analyses presented in the two preceding subsections, this section proposes a combined assessment approach aimed at enabling a streamlined, quantitative evaluation of urban green space actual suitability. This is achieved through the prior definition of standardized 'quality ranges'. The process begins with the selection – according to the prior analysis – of parameters impacting green space usability. For each selected parameter, threshold values, classification codes, and typological characterizations were defined and are presented in Tab.2.

Specifically, for the parameter "Class", it was deemed reasonable – within the scope of this assessment – to group certain categories according to their functional and experiential value. The "Park/Public Garden" and "Equipped" features, which typically offer the highest levels of usability and public amenity, were grouped under Category A. Under Category B, of intermediate quality, were included "Sporting" and "Associated with Services" features, as their accessibility is often restricted and their use generally limited, thus not ensuring full or inclusive enjoyment. Finally, Category C encompassed the "Residual", "Traffic-Enclosed", and "Other" features, representing green areas that are either not usable or are of marginal recreational value.

Regarding spatial extent, a minimum area threshold of 200 sqm was confirmed from the intrinsic features analysis. Green spaces below this threshold were considered episodic, minor fragments not indicative of planned or significant public green infrastructure, thus with a lower positive impact on liveability. For compactness, a threshold value of 0.12 was employed, consistent with the findings from the earlier subsection on intrinsic features; this value delineates minimally compact green areas, with an irregular and inconsistent

shape which limits the fruition or the contiguous visibility, thus impacting on the way people can live and perceive them.

	Parameter	Base category	Derived Category	Label	Potential combinations		
Intrinsic features	Class	Park/Public garden Equipped Sporting Assoc w services Traffic_enclosed Residual Other	Park/Public garden Equipped	A	A-hA-hC A-hA-lC A-lA-hC A-lA-lC	B-hA-hC B-hA-lC B-lA-hC B-lA-lC	C-hA-hC C-hA-lC C-lA-hC C-lA-lC
			Sporting Assoc w services	B			
			Traffic_enclosed Residual Other	C			
	Extension	Value [sqm]	> 200 sqm	hA			
			< 200 sqm	lA			
	Compactness	Value	> 0.12	hC			
			< 0.12	lC			
Extrinsic features	Usability	Free Limited Inaccessible	Free	F	F-lc-pk F-lc-npk F-gc-pk F-gc-npk F-s-pk F-s-npk	L-lc-pk L-lc-npk L-gc-pk L-gc-npk L-s-pk L-s-npk	I-lc-pk I-lc-npk I-gc-pk I-gc-npk I-s-pk I-s-npk
			Limited	L			
			Inaccessible	I			
	Centrality	Value (NACH R800) Value (NAC Rn)	Locally central	Lc			
			Globally central	Gc			
			Segregated	s			
	Mobility amenities	Cycleways Parking	Parking	Pk			
			No parking	npk			

Tab.2 Parameters selected for the qualitative assessment, categorization and possible combinations for green public areas.

In terms of extrinsic features, existing categorizations for Public Access ("Free", "Limited", "Inaccessible") and Parking Availability ("Yes", "No") were maintained, as for the measure of accessibility, categorized again into three classes: Locally central, Globally central, and Segregated. In summary, for each green area, Space Syntax quantiles were verified: if the area was within the top 20% quantile of NACH R800, it was categorized as Locally Central; if within the top 20% of NACH Rn, as Globally Central; otherwise, the area was classified as Segregated.

Tab.2 presents the summary of the considered categories and also illustrates the possible combinations of them, delineating the full range of green space typologies emerging from the selected categorizations. In total, 12 types of green areas according to intrinsic properties and 18 types of green areas according to extrinsic properties were identified, which in theory generate a potential number of 216 combinations. Compared to the original dataset (Tab.1), the information on the year of realization was excluded, as it is not qualitatively relevant for assessing current green space quality. Similarly, the presence of cycling paths was omitted, which may initially seem counterintuitive given their role in accessibility. However, in the context of this simplified tripartite classification – Low Suitability (LS), Medium Suitability (MS), and High Suitability (HS) – the presence of a cycling path was not considered a decisive factor in comparison to the more impactful features of Class, Public Access, and Centrality – thus just valuable in a logic of further more in-depth and granular studies. Fig.6 presents the matrix of all possible combinations between intrinsic and extrinsic features of green spaces.

Fig.8 Integrated assessment of the three case studies through the *overall suitability value* categorization and connected infographics.

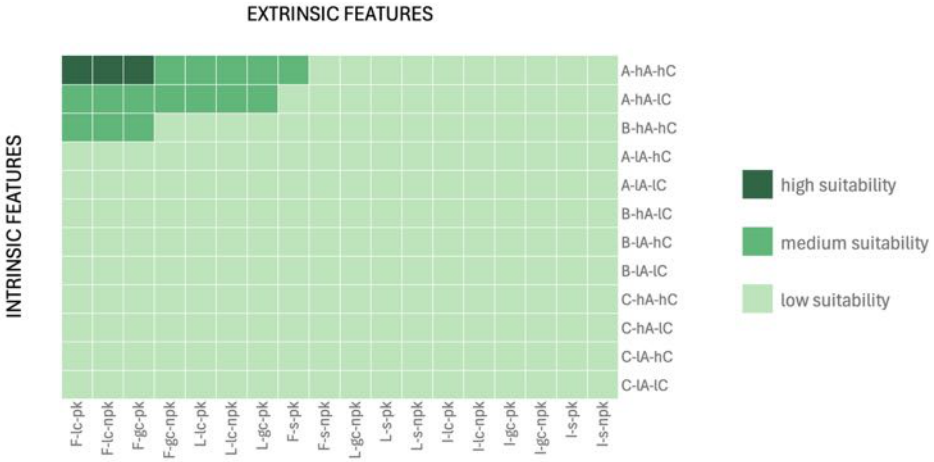
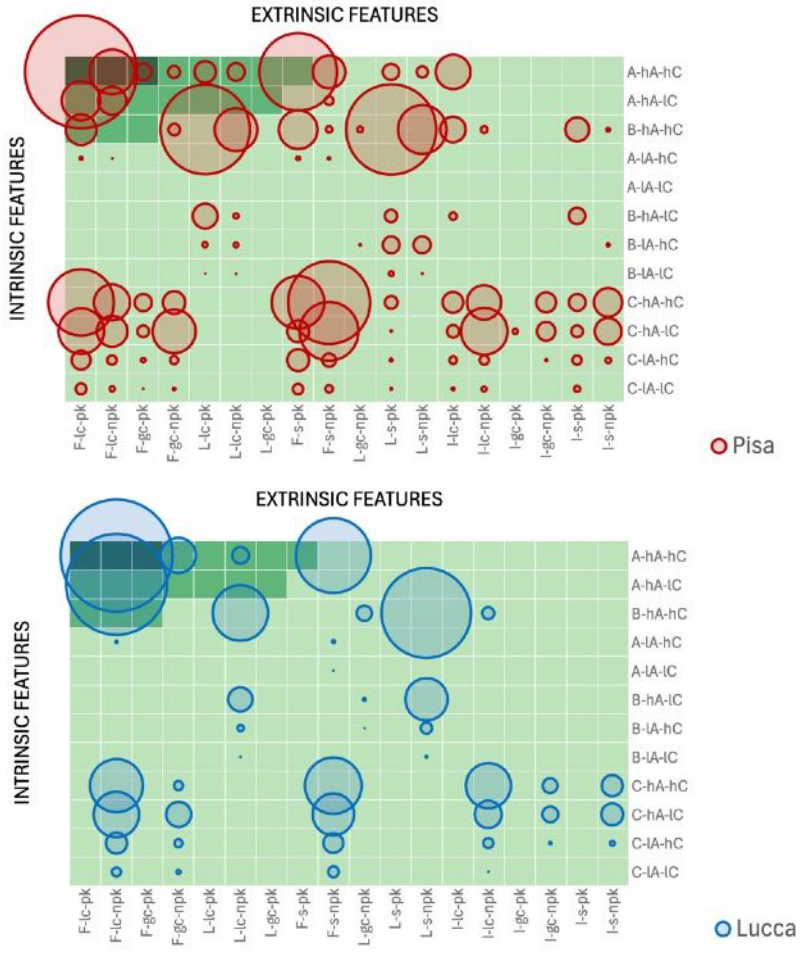


Fig.7 Waffle suitability chart representing the matrix used to categorize the green public areas in High Suitability (HS), Medium Suitability (MS) and Low Suitability (LS).

Intrinsic features are represented along the horizontal axis, while extrinsic features are organized along the vertical axis. High Suitability (HS) combinations are highlighted in light purple (n = 3), Medium Suitability (MS) in purple (n = 15), and Low Suitability (LS) in blue (n = 197). The spatial distribution of this classification is visualized in Fig.8, which allows for a comprehensive evaluation of the overall suitability of public green spaces by integrating both intrinsic and extrinsic characteristics. Additionally, a grouped bar chart illustrates the distribution of HS, MS, and LS green areas across the three case-study cities, expressed both in percentage terms relative to each city's total and in absolute values.



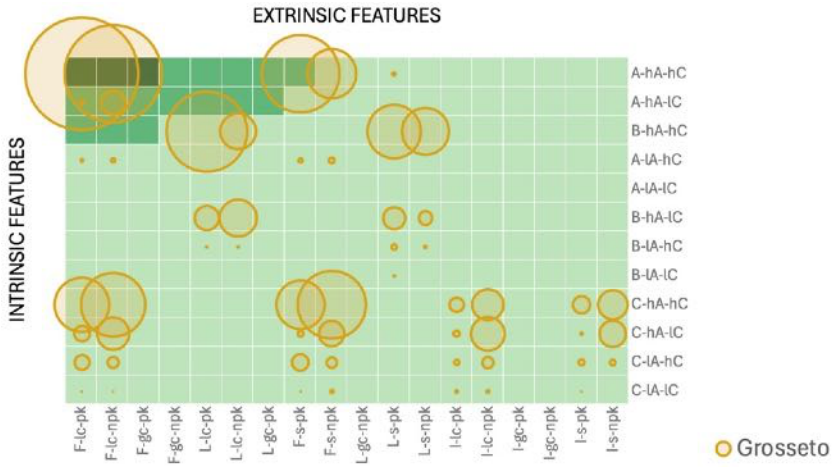


Fig.9 Bubble charts resuming the quantitative amounts (total area) per typology of green areas, obtained by considering both intrinsic and extrinsic features. The overlap with the waffle suitability chart highlights the clustering and prevalent typologies of green public spaces for each case study.

What emerges from this analysis is that only a low amount of urban green space can be considered high valuable in terms of liveability. Specifically, only 16.5% of green space in Pisa, 20.3% in Lucca, and 31.5% in Grosseto falls into the High Suitability category. In contrast, a substantial proportion – 71.8% in Pisa, 60.6% in Lucca, and 58.9% in Grosseto – is classified as Low Suitability, indicating that a significant share of public green areas exerts limited or negligible positive impact on urban liveability.

To provide a final, integrative layer of analysis, Fig.9 overlays variable-sized circles onto the Waffle Chart presented in Fig.7. The size of each circle is proportional to the total surface area associated with each suitability category, enabling a rapid visual interpretation of the typological composition of green spaces across the urban landscape. This visualization also reveals distinct spatial clusters, further highlighting the differentiated distribution of green space types – considering both intrinsic and extrinsic characteristics. By replacing traditional tabular formats, this representation offers a more intuitive and immediate understanding of the combinations of green space properties, serving as a valuable tool for interpreting complex spatial patterns in urban green infrastructure.

6. Conclusions

This contribute proposes an expeditious methodology for assessing the quality of green spaces, defined in terms of the effectiveness of their performance as services for health, recreational, and social activities of the inhabitants. The assessment of such effectiveness was evaluated both with reference to the intrinsic properties of individual areas designated as public green spaces and to the positional properties they actually assume in relation to the urban network and their actual accessibility.

The analyses, carried out on the three case studies of Grosseto, Lucca, and Pisa, showed that the provision of green areas, expressed solely through the numerical values of their extension, is entirely insufficient to provide a reliable indication of their actual performance quality. It emerged in all three cases that a large portion of public green space is of low 'quality' (categories: traffic-enclosed, residual, other), often corresponding to leftover areas along the edges of road infrastructure – spaces that are sometimes inaccessible due to being cut off by road networks, or generally residual elements in relation to built-up areas. The presence of urban parks, actually implemented in accordance with the standards imposed by Ministerial Decree 1444, is yet frequently marked by conditions of segregation from the street grid.

Interesting insights also emerge from the diachronic trend analysis, which shows that after 1968 – despite diverging planning priorities driven by each city's unique historical, urban, and morphological evolution – the typological composition of newly introduced green spaces varies significantly across cities. While Pisa

demonstrates a marked shift toward higher-quality green typologies, such as parks, equipped areas, and sports facilities, Lucca experienced more substantial growth in sports areas. Grosseto, within the broader context of general expansion, saw an increase across all typologies, including large areas designated as parks or public gardens. This pattern appears to reflect an attempt to compensate for the limited usability of green spaces by planning extensive park, equipped, or sports areas – even though these are often characterized by poor accessibility relative to their urban context. The findings from the analysis of extrinsic characteristics reinforce this interpretation, highlighting the limited integration of green areas into the urban path network. This is due to their peripheral locations, restricted (or even absent) accessibility, and very weak connections to the cycling route network.

The construction of a composite quality index, integrating both intrinsic and extrinsic characteristics, results in a distribution largely dominated by areas of low quality. The research offers the opportunity for further developments and exploration in various directions – for example, by integrating proximity-based indicators such as NAIN to assess potential supply-demand imbalance, or by assessing the amount of green space available to each resident within a certain distance from their home through the use of ISTAT census data, or by extending the analysis beyond green areas to include linear tree plantings and shaded walkways, thus accounting for green corridors and microclimatic comfort, also in relation to different population groups. These possible extensions would be particularly relevant in relation to the targets and principles outlined in the emerging Nature Restoration Law, which emphasizes ecological connectivity, social inclusion, and equitable access to high-quality green infrastructure.

All of this, while still far from offering a definitive interpretation of the issue, nevertheless provides some useful insights and, above all, highlights the need for a careful and detailed assessment of the settlement and performance quality of green areas – both for evaluating their actual conditions in specific contexts and, especially, for assessing and addressing their provisions within urban development or regeneration plans.

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