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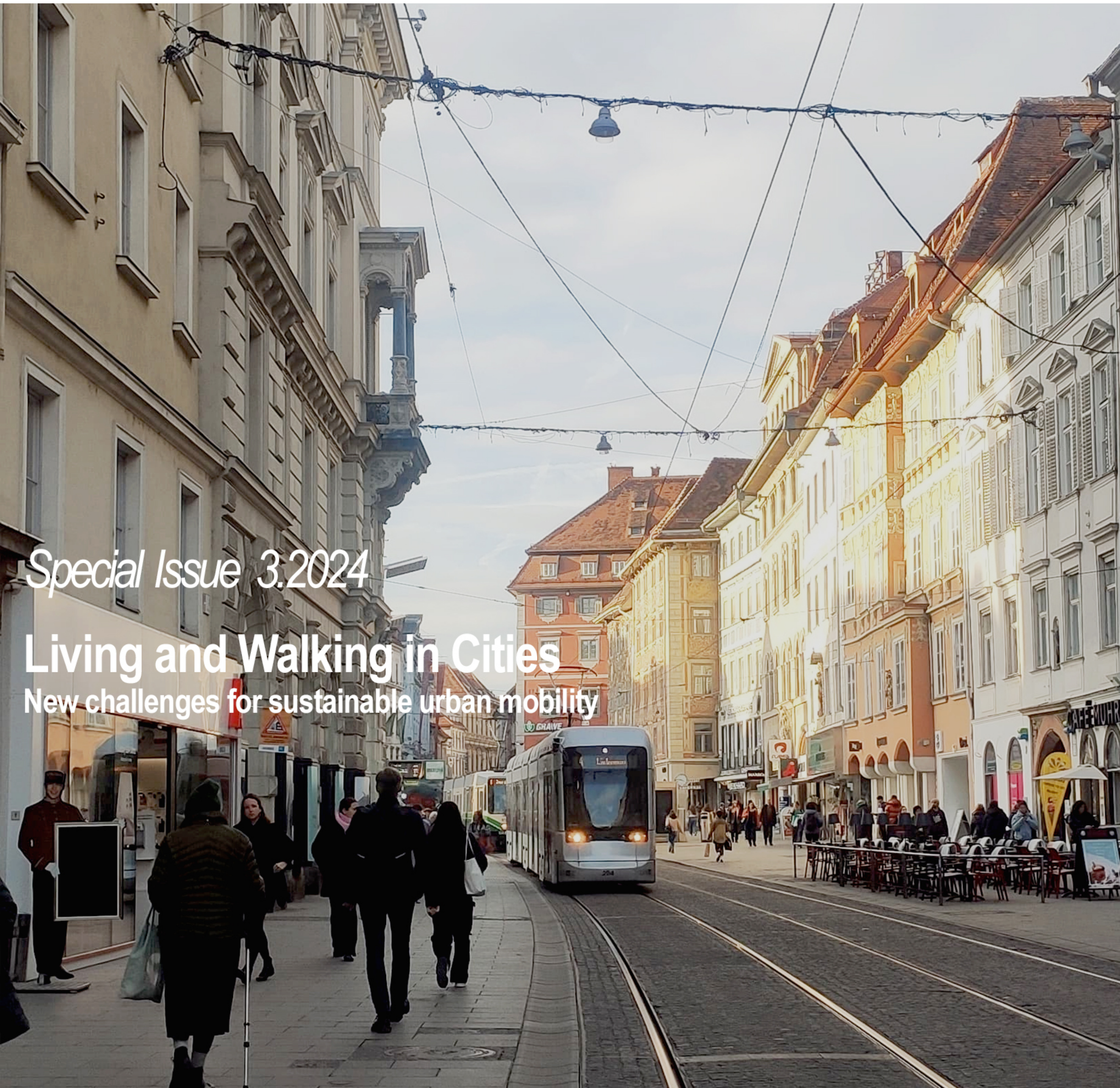

Special Issue 3.2024

Living and Walking in Cities

New challenges for sustainable urban mobility

This Special Issue intended to wonder about the new challenges for sustainable urban mobility, aligning with the European Sustainable & Smart Mobility Strategy. Contributions come from selected papers of the XXVI International Conference "Living and Walking in Cities" and have been collected around two main topics: the relationship between transport systems and pedestrian mobility and the transformative potential of temporary urban changes. Reflections and suggestions elaborated underline a collective great leap forward to reshaping urban mobility paradigms.

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Cover photo: Herrengasse street in Graz (Austria), baroque pedestrian avenue and centre of public life, provided by Michela Tiboni (June, 2024)

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EDITORIAL PREFACE

Special Issue 3.2024

Living and walking in cities: new challenges for sustainable urban mobility

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In recent decades, addressing urban mobility and liveability has become increasingly urgent due to environmental concerns, rapid urban growth, and evolving mobility needs. The continuous expansion of cities and the development of new technologies call for innovative solutions that can improve the city organisation by guaranteeing safe, efficient, lively, and environmentally friendly urban transport systems. The "Living and Walking in Cities" (LWC) Conference, held biennially, traditionally deals with urban mobility and quality of life in urban areas, emphasising vulnerable road users' accessibility and safety (Pezzagno & Tira, 2018; Tira et al., 2020; Maternini et al., 2021; Gargiulo et al, 2022; Maternini et al., 2024). The Conference is a platform for researchers, experts, administrators, and practitioners to discuss policies, best practices, and research findings from several perspectives. Therefore, it exemplifies the global commitment to scientific dialogue in solving urban mobility challenges.

This TeMA Journal Special Issue, inspired by the themes of the 26th LWC Conference, takes up the focus on "New Challenges for Sustainable Urban Mobility", aligning with the European Sustainable & Smart Mobility Strategy, which aims to reduce transport-related GHGs by 90% by 2050 (European Commission, 2020) and underlining a collective great leap forward to reshaping urban mobility paradigms. Therefore, the special issue aims at enriching the scientific and practical debate by addressing theories, empirical insight, methodologies, experiences, and techniques related to policy issues, best practices, and research findings. The volume includes fifteen articles, exploring multifaceted aspects of urban mobility and liveability, grouped into two primary thematic clusters.

The first cluster of articles examined the relationship between transport systems and pedestrian mobility, investigating various aspects and paradigms of accessibility, policies and the significance of mobility in an era of emergencies. It also delves into urban planning, emphasising the governance of urban and regional transformations in order to achieve more active and sustainable urban mobility while considering social and temporal implications.

In this context, Spadaro & Pirlone (2024) explored the intersection of mobility, participation, and sustainable regeneration in urban projects. Utilising the 4-helix innovation framework involving citizens, universities, companies, and administrations, the authors emphasised participatory policies for sustainable urban mobility. The study focused on the Liguria Region (Italy), which included case studies from Prà-Palmaro waterfront, Busalla, and Albisola Superiore. The approach showed the relevance of collaboration in creating resilient, sustainable urban environments. Fusi & Tiboni (2024) focused on the integration of urban and transport planning in medium-sized cities. The authors demonstrated how the strategic urban planning tools can combine design and operational layers to enhance urban mobility. The results for the Brescia (Italy) case study showed the feasibility and benefits of integrated planning approaches, emphasising the relevance of aligning urban and transport planning to improve sustainable mobility. Moretti & De Lotto (2024) investigated the relationship between land use and CO_2 emissions from road transportation in the Province of Pavia, by using the INEMAR inventory. By evaluating the inter-scalar relationship between the Province and the Municipal scales, the article provided insights into land use influences on pollution levels, i.e., the impact of urban density and traffic flows on pollution. The methodology is based on the integration of geographical data and emission factors, to propose strategies for reducing emissions through integrated mobility systems and sustainable urban planning, so fostering the mitigation of climate change.

Further exploring accessibility paradigms. Pellicelli et al. (2024) proposed a protocol to assess smart and active mobility in urban regeneration projects. As applied to medium-sized cities in Emilia-Romagna (Italy), the protocol identified and applied specific indicators to measure the impact of regeneration on mobility and accessibility. The study set up the guidelines for integrating active and smart mobility into urban regeneration processes, emphasising the potential of these approaches to revitalise medium-sized cities. Pantaloni et al. (2024) developed a method for assessing the proximity, accessibility, and usability of green spaces, aiming at maximising cultural ecosystem services. The method integrated traditional spatial planning tools with ecological performance approaches, by associating ecological and socio-demographic data. As a result, the authors provided guidelines to support public administrations in enhancing green space distribution and developing a Green Infrastructure strategy. Türken & Conticelli (2024) explored how new technologies affect pedestrian walking behaviour. The authors reviewed traditional and innovative tools, such as GPS, GIS, video analysis, and machine learning, analysing their integration and effectiveness. The results showed advantages, limitations, and potential improvements in digital tools for improving data collection and analysis, supporting walkability assessments, and enhancing walking experiences.

Addressing the theme of mobility in an era of emergencies, Nifosì et al. (2024) developed an "Atlas of Coastal Roads" to address climate change vulnerabilities and opportunities for adaptation in Italy's coastal regions. The Atlas integrated quantitative and qualitative indicators to assess geophysical, climatic, and socio-economic risks. By providing a trans-scalar tool, the research aimed at guiding stakeholders in developing tailored adaptation strategies to enhance coastal infrastructure resilience and to support socio-ecological transitions.

The second cluster of articles focused on the transformative potential of temporary urban changes and the concept of the 15-minute city. It explored how short-term interventions can lead to permanent improvements in urban mobility and public spaces, emphasising accessibility, walkability, and the integration of transport and urban planning principles. The primary focus is on public space planning and design, encouraging social uses and the adoption of healthier lifestyles and addressing social and spatial equity for active mobility.

Rainieri et al. (2024) examined the role of active mobility in promoting social sustainability. Using a Rapid Evidence Assessment method, the study reviewed how active mobility impacts on social sustainability, particularly its alignment with Sustainable Development Goals (SDGs). The research findings highlighted how some variables influence active mobility and its benefits, such as reduced traffic congestion, improved air quality, and enhanced social equality, and provided a comprehensive framework for future research and policy development. Bianchi & Moscarelli (2024) delved into the redesign of school squares to promote public and outdoor activities. The authors proposed a methodology for classifying and redesigning school squares to enhance public utility. Analysing over 600 school squares in Milan, Turin, and Varese, the study categorised them into four typologies and suggested guidelines for interventions to improve each type. Similarly, Rossetti et al. (2024) introduced a GIS-based methodology to assess walkability in school vicinities. The authors developed a School Walkability Index (SWI) for 21 schools, identifying areas with low walkability and pinpointing critical issues. By analysing pedestrian catchment areas within 3, 10, and 15-minute walking distances, the research provided valuable insights for public administrations to improve school accessibility and enhance the surrounding public spaces.

Shifting the focus to the transition from temporary to permanent urban changes, some articles explored how short-term interventions can lead to lasting improvements in urban mobility and public spaces. Staricco et al. (2024) analysed street experiments of temporary pedestrianisation projects in Turin (Italy) as part of the Torino Mobility Lab. Since street experiments aimed at promoting active mobility by reallocating road space, the study focused on the monitoring and evaluation process to identify barriers and factors that influence the transition from temporary to permanent, sustainable urban mobility solutions, e.g., pedestrianisation. The results emphasised the potential of public participation and adaptive urban planning in achieving long-term urban transformations. Boglietti et al. (2024) explored the use of tactical urbanism as a strategy for climate change adaptation. Analysing the "SpaziAttivi" project in Brescia (Italy), the study outlined the methodological process for selecting areas for intervention, emphasising the importance of community engagement and participatory design in creating resilient urban environments. Key outcomes included the enhancement of urban microclimates and the promotion of sustainable mobility.

Further exploring the time-space design for the X-minute cities. Guaiani (2024) examined the reuse of urban spaces designed for automobiles by comparing historical, car-dependent, and sustainable city models. The study analysed the cases of Venice, Urbino, Milan's San Siro quarter, and Bologna's Pilastro quarter to illustrate how different urban forms impact on mobility. By integrating spatial and temporal dimensions, the article identified design principles for transforming car-dominated areas into walkable, sustainable environments, emphasising the importance of polycentric urban structures and mixed land uses. Sezer et al. (2024) applied the principles of Transit-Oriented Development and the 15-minute city concept in Palermo's rail station areas. The methodology combined qualitative and quantitative indicators to assess accessibility and urban quality, i.e., assessing social, functional, and environmental features of two station vicinities. The results highlighted the potential for TOD and 15-minute city synergies to enhance public transport efficiency and reduce car dependency, promoting sustainable urban mobility. Mazzola & Bove (2024) assessed the role of sustainable mobility in urban regeneration through the "GBC Quartieri protocol" and focused on the neighbourhood named Le Albere in Trento (Italy). The article examined the integration of mobility solutions like cycling infrastructure, public transport access, and pedestrian pathways. The results highlighted the relevance of mobility in achieving sustainable urban development and provided recommendations for enhancing connectivity and reducing environmental impacts in new urban districts.

In conclusion, this special issue provides a comprehensive and in-depth overview of the challenges and solutions for sustainable urban mobility, promoting scientific dialogue and practical innovation to improve the quality of life in cities.

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Mobility, participation and sustainable regeneration. Urban projects in Liguria Region

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Abstract
The paper reports different experiences in which mobility, participation and sustainable regeneration represent fundamental issues for our cities. The applications are developed in idea competitions promoted by municipal governments and associations. Rethinking mobility and orienting actions towards sustainability means putting people at the center of urban strategies. In this context, the 4 innovation helix framework, and so, the involvement of local actors: people, university, company and administration, is indispensable for guiding society towards sustainable development according to 2030 Agenda. In the experiences illustrated, the role of the University emerged as a connector capable of collaborating together and building synergies between the various actors involved with the common objective of improving the liveability of our cities. Liveability which is closely linked to the improvement of mobility services and their intramodality with important repercussions on the accessibility of services. The actions undertaken for more sustainable mobility lead to a path that increases the demand for integrated services for the movement of people and goods but also the attractiveness of the area from an environmental, social, tourist and economic point of view. The urban projects presented were carried out as part of university courses in collaboration with public administrations of the Ligurian Region.

Keywords
Sustainable mobility; Participation; Regeneration project.

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1. Introduction

Mobility, Participation and Sustainable Regeneration are fundamental and synergistic topics in today's cities.
Agenda 2030 in 2015 underlines attention to the urban reality, given that the majority of the population will increasingly live in this reality. As is known, the document is made up of various objectives and, in this context, Goal 11 "Sustainable Cities and Communities" is of considerable interest. This Goal aims to make cities and human settlements inclusive, safe, durable and sustainable.
In this context, mobility is a priority rethinking sustainable mobility also means promoting urban regeneration actions according to the principles of Agenda 2030. Sustainable mobility is the ideal model of a transport that minimizes environmental impact while maximizing efficiency, intelligence and speed of travel.
Specifically, Goal 11 of the 2030 Agenda aims by 2030 to: "provide access to safe, affordable, accessible and sustainable transport systems for all; improve road safety, particularly by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons (11.2) and reduce the negative per capita environmental impact of cities, particularly with regard to air quality" (11.6) (UN, 2015).
Urban mobility infrastructure must contribute to the attractiveness and environmental performance of urban areas. Such mobility must be sustainable according to the three aspects: environmental, social and economic. With regard to the first aspect, it is important to reduce harmful emissions into the atmosphere; about the second, it is essential that mobility is inclusive and accessible (for different types of users, means of transport, times of the day, …) and finally in coherence with the third aspect, it must promote the creation of new jobs. Indeed, thanks to sustainable mobility, benefits in terms of territorial, social, environmental and economic development is possible to have. Interventions for sustainable mobility increase the demand for integrated services for the movement of people and goods, consequently reducing air pollution, noise, congestion and accidents and recovering degraded public places.
Moreover, when talking about sustainability, another concept is also crucial to introduce: the participation of different territorial actors. Citizen involvement aims to improve decision-making by producing better policies, building trust, gaining acceptance of policies and sharing responsibility for policy making (OECD, 2003). Goal 11 of Agenda 2030 itself aims to "increase the capacity for participatory and integrated planning and management of human settlement in all countries" (11.3) (UN, 2015). The term participation refers to social processes in which citizens, or representative groups of citizens and associations and administrations (responsible for the object discussed) are involved. These processes are based on dialogue and have as their goal the resolution of a collective situation perceived as problematic or the choice of a decision in the public interest.
Individuals, groups and organizations are given the opportunity to participate in decision making that affects them or in which they have a relevant interest (Elelman & Feldman, 2018).
All actors are called to contribute actively; the role of public administration is important in this context. Local authorities -given their proximity to the territory- are called to the forefront to take a central role in implementing planning, financing and evaluation measures (European Committee of the Regions, 2019).
There are various techniques related to participatory processes. It can be quantitative, qualitative and participatory; different are the corresponding methods, i.e. through the use of interviews, questionnaires, meetings, round tables, both carried out in person and online. For this last aspect, the pandemic triggered an important acceleration that involved the entire population, in different age groups.
Participation today responds to the demands dictated by the European Union to implement projects and planning tools at the urban and/or territorial level attentive to sustainability declined in environmental, economic and social.
The paper reports the results of some experiences aimed at initiating regeneration processes from participatory policies and strategies aimed at sustainable mobility planning.

2. An approach for the integration of mobility, participation and sustainable regeneration themes in urban planning projects

The paper presents an approach that aims to integrate themes such as Mobility, Participation and Sustainable Regeneration into urban planning projects.
This approach has been developed in projects promoted by municipal governments and associations. These experiences have led to the drafting of specific urban planning projects.
In the last years, the Urban planning technique course at the University of Genoa (where the authors teach) participated in urban regeneration competitions. Such competitions, promoted by public entities, have been carried out to stimulate active participation. All stakeholders have benefited from this opportunity: students have been able to work on current issues by continuously confronting to the territory and public administrations; the municipality has been able to develop innovative and sustainable project ideas, which sometimes, have been partly implemented. The Course laboratory thus became operationally the territory under study, to be analyzed and redesigned where necessary.
Sustainable mobility was one of the pivotal issues considered in urban planning projects aimed at regeneration. Specifically, key aspects considered in these projects were: soft mobility path, public transport, intramodality, temporal urban planning, green corridors, street furniture, resilience, use of sustainable means, bike-car sharing, materials for safety (Fig.1).

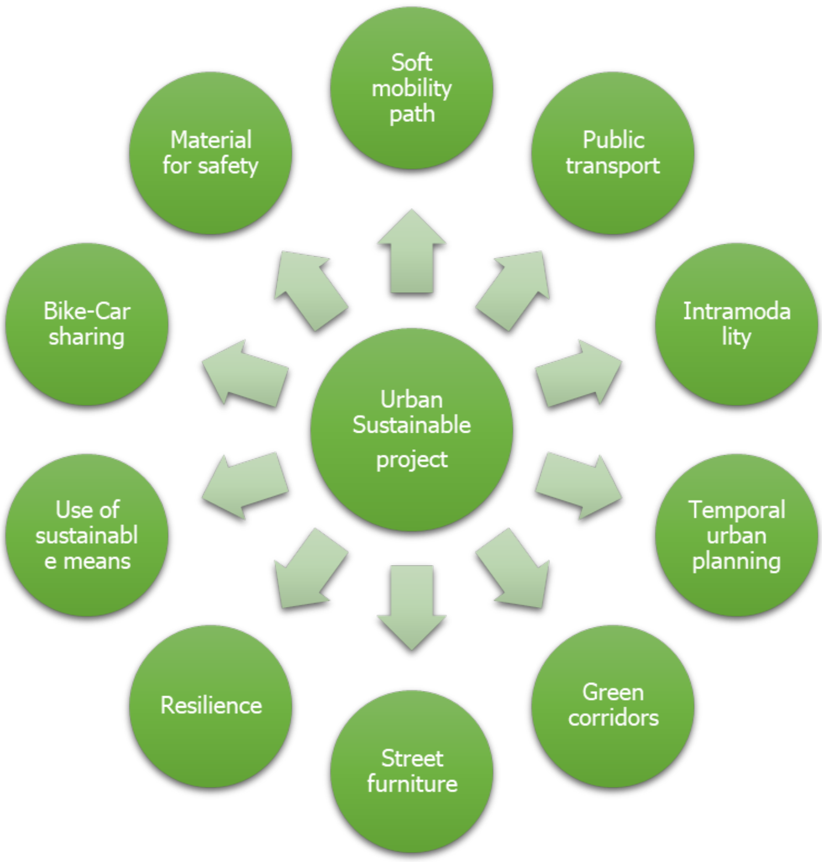


Fig.1 Urban Sustainable project: key aspects

The methodological approach, stems from previous research (Pirlone & Spadaro, 2022) and involves several phases that were developed taking into account the participation aspect as well (Fig.2). The phases and the results obtained are then merged with the technical aspects and knowledge of those who live, work and know an area.

The first step is the cognitive phase, which was based on the retrieval of initial documents and information, such as statistical yearbooks, from the study of current urban planning instruments and the collection of information reported by the actors involved in the participatory process. This phase included questionnaires, interviews and in-person or online meetings.

Fig.2 A sustainable participatory mobility approach

The second step was the analytical phase. This phase included different types of partial analyses aimed at providing a fundamental overview for the third phase (planning). Analyses typical of the business world, but now well established in urban planning, such as SWOT (Strengths, Weaknesses, Opportunities and Threats) and PEST (Political, Economic, Social and Technological), were used. These methods allow the identification of strengths, weaknesses, critical issues, opportunities and to take into account political, economic, social and technological aspects. Another type of analysis took into account the views of the different actors involved in the activated process. The combination of the two types of analysis, objective (the first) and participatory (the second) allow us to proceed with a complete state of the art to the third and final phase. It consists of planning objectives and interventions. The main output obtainable from this phase is the development of a general master plan and the in-depth analysis, through detailed details but also sections and elevations, of some key elements defined in the project.

Several guiding parameters were also considered for each intervention. For example, for cycling, these include: safety, integration, functionality, intermodality, use of new technologies and design. The planning phase systematized what emerged from the previous phases and, also thanks to the participation of the actors involved, arrived at the definition of policies/strategies to promote, as far as the mobility theme is concerned, intermodality, car-bike sharing, ICT incentives and tools, ... up to the co-design of the interventions to be implemented (routes-bicycle lanes, pedestrian walkways, ...).

In this phase, the concept of experiential participation, based on the experience of the actors involved, was applied. In the definition of a new bike route, for example, experiential participation is important because it allows to support the design by following the indications of those who use the bike in today's without a real infrastructure present in the area (highlighting why they ride precisely that route, for slope, rather than for

safety, ...). All phases are therefore participatory because within each one the different stakeholders were involved to identify projects that would lead to an improvement in the quality of life for the population (both residents and tourists). In fact, the idea of participation developed is intended to accompany the entire cycle of public policy formulation and implementation (including the moment of management and implementation). In this way, everyone, and in particular the population, becomes an active participant in the definition and subsequent implementation of projects and in taking care of the commons.
The results of these experiences have been the implementation of participatory urban planning projects aimed at improving realities considered significant such as sustainable mobility.

3. Urban projects: the integration between Mobility, Participation and Sustainable Regeneration in Ligurian case studies

The Urban planning course of the University of Genoa has participated in 3 calls for projects promoted by public administrations in the Liguria region from 2020 to the present.
The competitions have been in the municipalities of: Genoa, Busalla and Albisola Superiore (Fig.3).

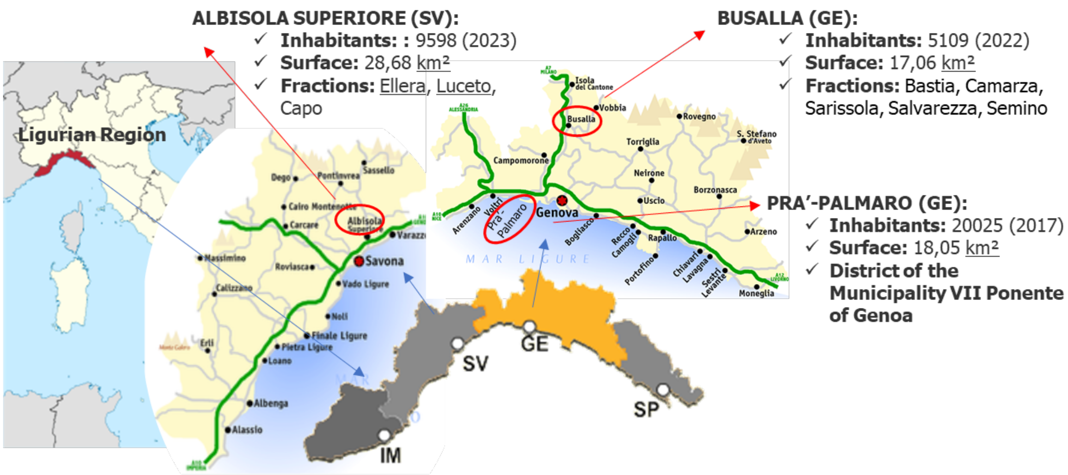


Fig.3 Case studies in Ligurian Region

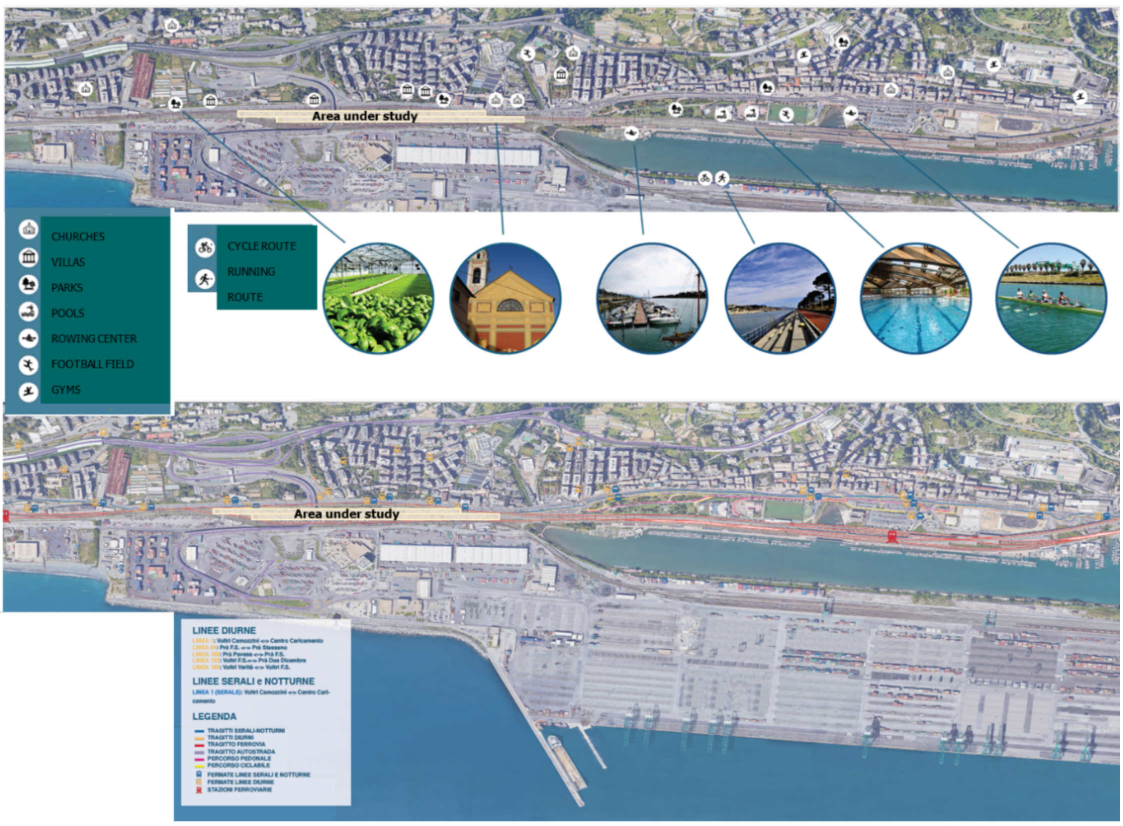
In 2020, students of the Urban planning course were invited to participate in the competition: "Let's give the sea back to Pra' – Palmaro", promoted by FondAzione PRimA'vera and Comunità Praese, under the coordination of Municipio VII Ponente and the Municipality of Genoa.
In 2021, the course was invited by the City of Busalla to participate in the initiative "Busalla twenty twenty-one_Redevelopment of urban mobility and recovery of areas along river Scrivia".
Finally, in 2022, University were invited to participate in the "Arbisöa Regeneration" competition, promoted by the City of Albisola Superiore.
Although the competitions were promoted by public administrations with different characteristics, in terms of size, geographic context (on the sea or in inland area), vocation (residential, tourist, industrial, …), in all of them the theme of participatory sustainable mobility was central. In these experiences, two other important aspects related to participation are that the actors involved, their skills, the dedicated time and available funding are channelled and planned to achieve the common goal of improving the quality of life of the inhabitants. And that cooperation is seen as a tool that allows: sharing knowledge and innovations; create a society with greater capacity to act; create participatory regeneration projects that aim for the safe, sustainable, circular and resilient development of the territory.
The following paragraphs report the application of the phases of the approach presented (section 2) and the results obtained in the three collaboration experiences between universities and the territory.

3.1 The case study of waterfront of Prà Palmaro (Genoa)

This initiative aimed to contribute to the regeneration of the Praese waterfront in order to improve the livability of the neighborhood. Following the relocation to the sea of the Genoa-Ventimiglia section of the railway between Rio Branega and Rio San Giuliano, the idea of the competition was born. It consisted of creating a promenade along the sea, with trees and different solutions to separate the path from the port and the new railway. The event to start the competition was conducted telematically (given the health emergency that had arisen) in March 2020 and the design work was concluded in June 2020, resulting in an award ceremony in December 2020 for the four participating student groups. The initiative led to the University's participation in a Technical Working Table in the area and the projects developed included the participation of the local population in the final judging of the competition.

The theme of Mobility has guided the development of urban planning projects. The public mobility service within the project area is managed by the company AMT Genova S.p.a. The area under study develops mainly along the Via Aurelia, from the end of the Genova Voltri area up to the center of Genova Prà, going towards the center of the city. The area is located in the middle of the two Municipalities and corresponds to the ancient Prà Palmaro. The bus lines extend across this territory with five daytime bus lines, which extend up to the heights of Montanella, Stassano and Pavese; the two night lines, on the other hand, are mainly on the Via Aurelia and connect the first Voltri to Piazza Caricamento and the second from Voltri to Nervi. As regards the railway, the area develops adjacent to the Genoa-Ventimiglia line and there are the two stations Genova Prà and Genova Voltri. The planning already takes into consideration the new project for an auxiliary stop between the two mentioned, which will be named Prà-Palmaro station. In the area examined, the motorway exit from the Genova Prà toll booth is also worth mentioning, which constitutes an important commercial intersection with the port basin and the new container terminal (Fig.4a).

During the application, a phase dedicated to the analysis of the material found is then developed. In particular, Fig.4b shows the SWOT analysis developed.



(a)

(b)

Fig.4 Pra'-Palmaro Case study: (a) Knowledge Phase: area under study inspection and mobility systems; (b) Analysis phase: the involvement of population; observation and proposal

The proposed master plans, following the cognitive and analytical phase, have therefore considered several of the key aspects fundamental for urban regeneration: in addition to sustainable mobility, and in particular soft mobility (pedestrianism and cycling) as continuity of travel, the green urban (as continuity of the green infrastructure), the enhancement of the identity of the place and local traditions, the use of ICT tools and the introduction of clean energy solutions. All the projects implemented sustainable mobility interventions. Paths for soft mobility i.e., for pedestrians and cyclists, shaped public spaces with a different solution along the sea channels or above with bridges and floating platforms. Intermodality between existing public services bus, train and the new bicycle and pedestrian routes enabled sustainable extension and connection between the city and the port. The feasibility in economic terms of the projects was assessed by reasoning on a budget equivalent to those of a small- to medium-sized P.O.R. (European-funded project).

For the creation of cycle paths, solutions have been proposed, taking Northern European cases as examples. The city of Genoa often suffers from flood phenomena due to torrential rains that sewers and urban drainage systems were never designed to manage. It is possible to use the existing space under the cycle paths to create trenches for the passage of rainwater. The modular panels that cover the boxes are light and designed with safe materials for the passage of bicycles, while the collected water can flow inside the canal, subsequently channeled into the microelectric systems and therefore also used for energy production.

To enhance the traditions of the area, the area was designed according to the conceptual development of an ancient terrace (typical of the Liguria region) re-adapting the spaces intended for commercial establishments and services that could serve the nearby railway station and the cycle path. The main intended uses could in fact be shops dedicated to bike sharing or technical assistance and catering establishments, which could therefore integrate with the surrounding areas. The strip could be completed with two cycle paths, one of which is integrated within the planned water channel, through an innovative vision of the cycle path that completes the green redevelopment of the area.

As regards the resilience of the urban space, in the project, through the use of floating wooden rafts, the possibility of creating different configurations on the water channel is envisaged.

Urban resilience refers to the ability of an urban system—and all the ecological and socio-economic networks that make it up on a temporal and spatial scale—to maintain or quickly return to the desired functions in the face of a disturbance, adapting to change" (Collier et al., 2016).
These rafts can in fact create bridges and therefore transversal connections dedicated to soft mobility, to pass from one side of the canal to the other or transform into squares. These are floating modules (2m x 6m) which are tied together via rings placed on all sides of the module, into which pins are inserted to lock them together and secure them.
In the end mini wind turbines, photovoltaic cells or mini water turbines were also designed along the bicycle/pedestrian routes to promote energy sustainability (Fig.5).

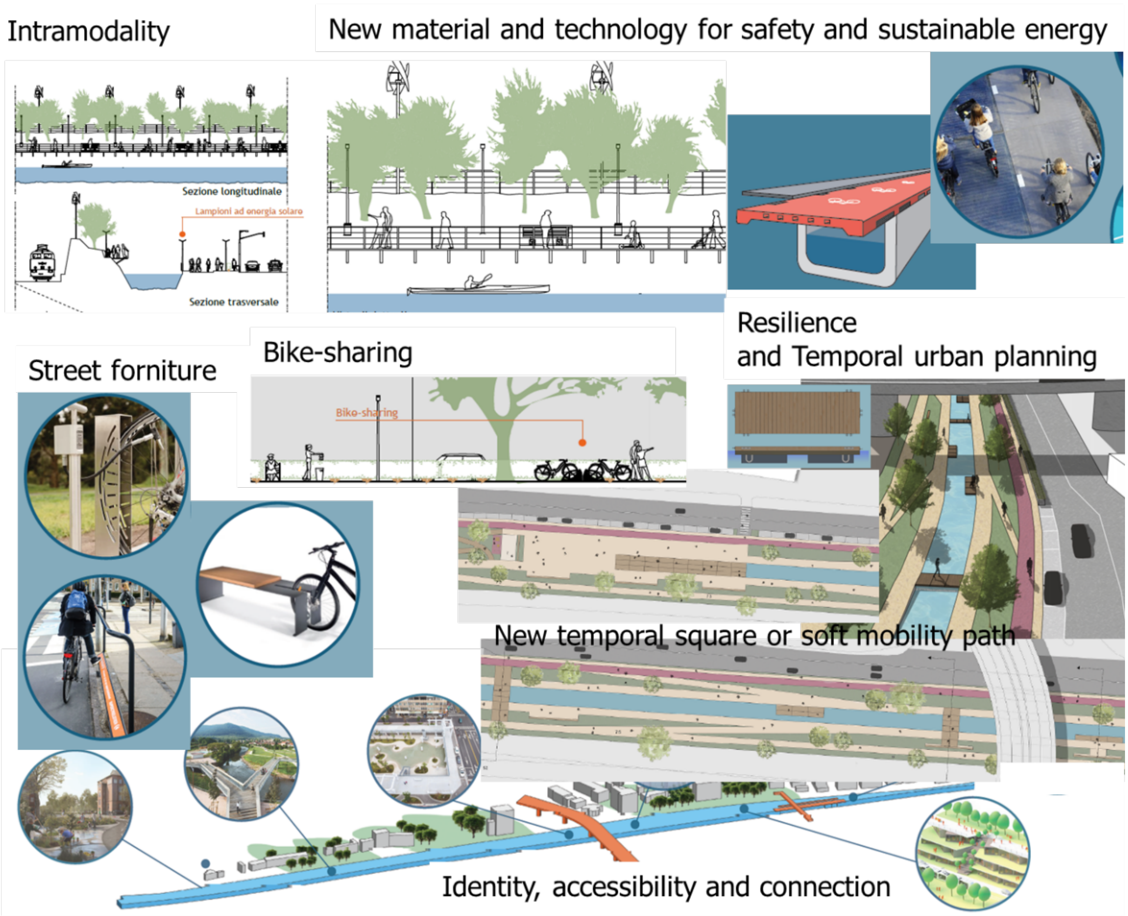
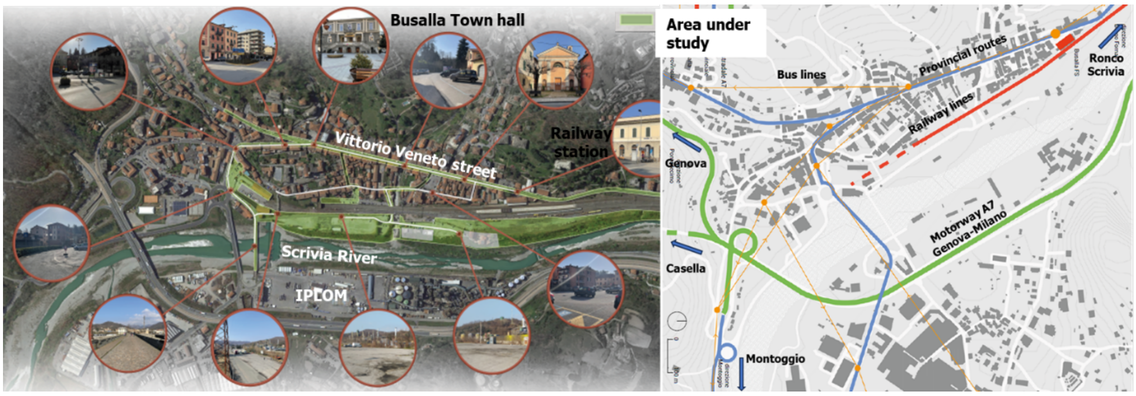


Fig.5 Case study Pra'-Palmaro (Ge): key aspects applied

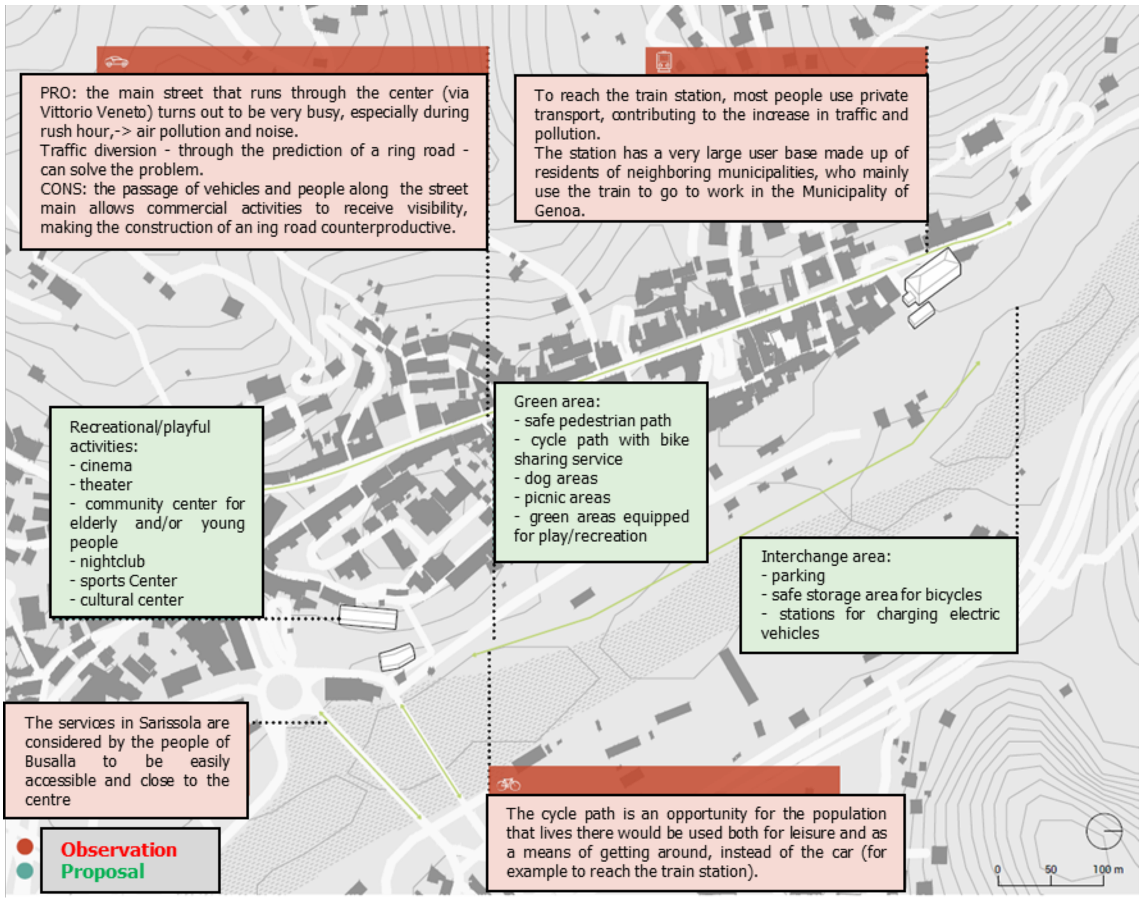
3.2 The case study of the city of Busalla

In 2021, the Urban planning course was invited by the City of Busalla to participate in the initiative for the redevelopment of urban mobility and recovery of areas along river Scrivia, favoring intermodality with rail and public transport. The interventions were aimed at improving air quality for better livability. The competition born following the inclusion of the bypass planned by the municipal urban plan in a narrow area between the Scrivia river and the Genoa-Arquata Scrivia railway (Via Busalla). The initiative consisted of reorganizing urban mobility, vehicular but also bicycle-pedestrian, favoring intermodality with rail and public transport from all over the valley through an interchange parking lot. The launch event was conducted telematically (given the protracted health emergency) in February 2021 and the urban planning projects were finalized in May 2021, with the subsequent public event held in July 2021 during which the project were displayed by the five participating student groups.

Busalla is a municipality in the metropolitan city of Genoa, located in the upper Scrivia valley, north of Genoa. The urban area develops mainly to the left of the Scrivia stream while on the west side there is the IPLOM petrochemical refinery. The area is entirely included in the Antola regional natural park and is one of the 45 municipalities of Liguria that are part of the catchment area of the Po river. The territory is crossed by the SS35 dei Giovi and the SP226 of Valle Scrivia: the first crossing the Passo dei Giovi allows the road connection with Mignanego and Ronco Scrivia, while the second, together with the SP63, connects it with Savignone. Other roads are the SP9 of Crocefieschi to reach the town of the same name and the SP53 of Bastia. Busalla has a toll booth on the A7 motorway and a railway station, the closest on the Turin-Genoa line (Fig.6a).



(a)



(b)

Fig.6 Busalla Case study: (a) Knowledge Phase: are under study inspection and mobility systems; (b) Analysis phase: the involvement of population; observation and proposal

Participation, as illustrated in the approach, was an aspect that was considered in all phases of the urban planning projects implemented. During the laboratory the University of Genoa has initially collaboration with the municipal administration and with population in order to develop participatory projects. Population involved through questionnaire, circulated on social media, and specific interviews carried out during the inspections to find out both the opportunities and the needs, in terms of lack of services/activities, that the different activity groups have shown. Final closing event open to all as an opportunity to inform and get feedback on the effectiveness and feasibility of what was proposed. Fig.6b shows an elaboration which concerns precisely the participatory phase developed in the analysis and evaluation phase of the planning scenarios examined. In particular, the observations and therefore the pros and cons of the strategies investigated are shown in red and the proposals are shown in green, also in terms of new uses and infrastructures that the population has identified as useful for the Municipality.

Once the cognitive and analytical phase was completed, we moved on to the definition of the master plans which considered several of the key aspects identified as useful for urban regeneration. Busalla is a city that has traffic problems, without green areas of a certain consistency and with the presence of an important petrochemical refinery, which affects not only from a visual point of view but also from an olfactory point of view. Therefore the projects focused on the need to integrate green areas and new routes dedicated to soft mobility in order to make it more accessible, safe and comfortable for all users. Not forgetting the enhancement of the identity of the place and local traditions, the use of ICT tools and the introduction of solutions to improve air quality.

Fig.7 shows some of the key aspects applied from the urban planning projects for the Busalla case study.

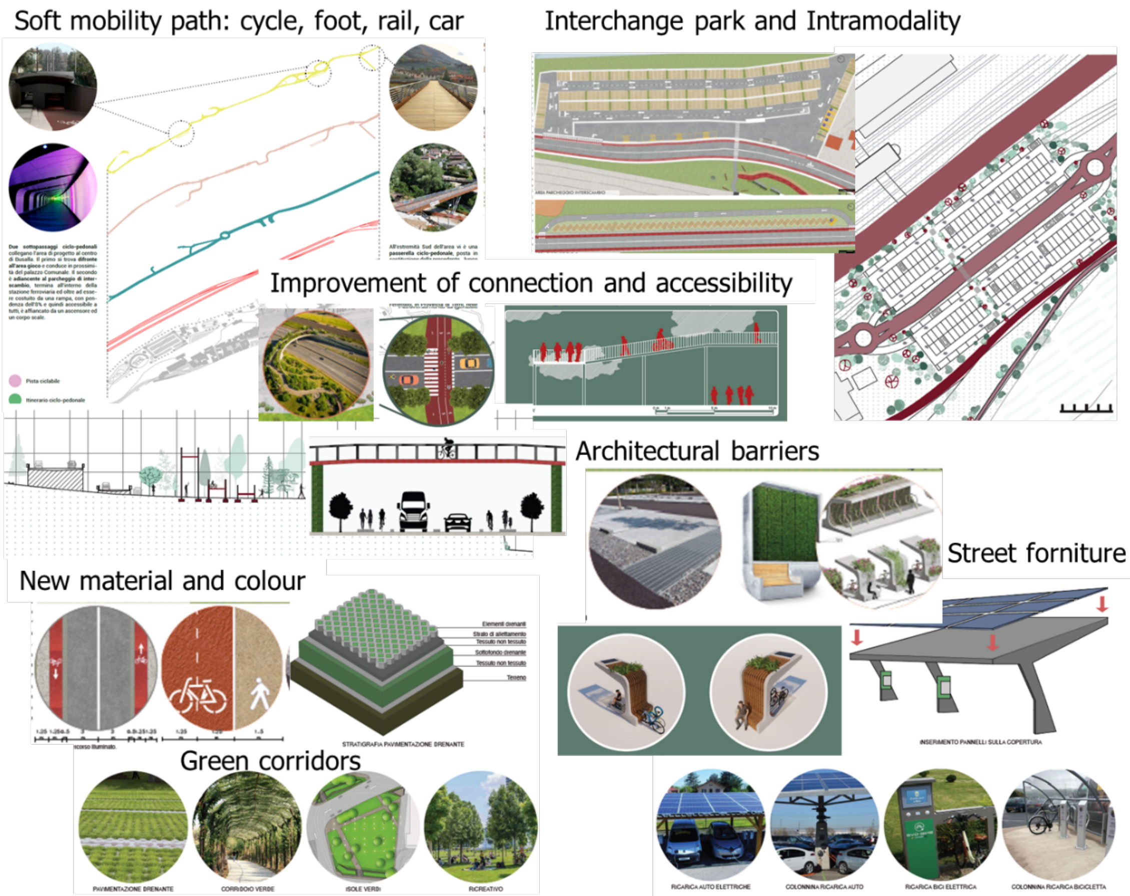
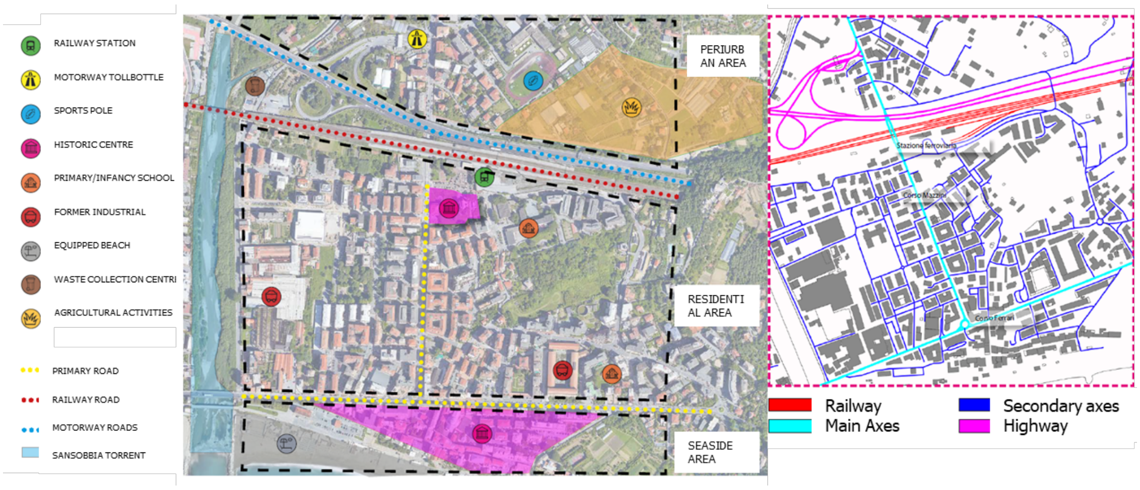


Fig.7 Case study Busalla (Ge): key aspects applied

The projects implemented focused on a new cycle path and the creation of green, safe and equipped routes for cyclists. These routes were identified within the study area and planned to ensure their continuity, and so the accessibility, in the surrounding area to allow connections to various strategic points for the municipality. The design of the route, i.e. the materials and colours of the planned furnishings and services, give the project a sense of unity. With regard to the furnishings, bike-sharing shelters and sustainable bike racks have been planned, integrated with solar panels to produce energy for recharging the bikes themselves, but also with moss-covered panels to improve air quality. The project was enriched with the creation of an interchange car park that could constitute the arrival point for the inhabitants of the valleys who use the Busalla station to reach their workplace. The objective was in fact to create an intermodal hub between train, bus, bike, on foot and car, also with safe parking areas for bikes and the possibility of a bike and car service sharing to promote a new mobility system that aims to sustainability. The ideas proposed also aimed to focus on the concept of resilience and versatility to create new spaces for everyone characterized by greenery, not only thinking about the present but also about a medium-long term, with elements that are largely non-structural but temporary and easily adaptable to different uses, so as to create areas that can be adapted over time, depending on the needs of the community. In this sense, temporal urban planning was used to plan the opening and closing times of certain streets/roads to leave more space for the creation of 30 zones and the free mobility of pedestrians and cyclists.

3.3 The case study of the city of Albisola Superiore (SV)

In 2022, students were invited to participate in the competition promoted by the City of Albisola Superiore.
The competition was launched on 21 February through a mixed-mode event (online and in-person) and ended in June. This initiative aims to realise urban regeneration interventions in the area of Albisola Superiore, in particular by providing for the realisation of soft mobility routes capable of connecting the three areas that characterize the municipality: periurban area, residential area and seaside area (Fig.8a). These interventions will benefit both inhabitants and tourists by improving the quality of life, reducing pollution and increasing sustainability.
Albisola Superiore is a municipality in the province of Savona, on the western Riviera of Liguria characterized by the presence of both the sea and mountains at a short distance from each other. The municipality is made up of 3 hamlets: Ellera, Luceto, Capo. Albisola Superiore is crossed by the Sansobbia stream and its main tributary Riobasco. It is internationally famous for its ceramic work. The territory has the typical Ligurian morphology, upstream the hilly and mountainous areas of the Apennines rise but the locality develops mainly on the coast. Albisola is mainly appreciated for its summer holidays due to its beach and sea, and in winter it is favored by its mild climate. Appreciated from a tourist point of view for the sandy beach, the picturesque bay, and the easy communications with the nearby cities of the coast and the province of Savona, thanks to the fact that it is crossed by the Aurelia, the possibility of being reached by the motorway and with the railway.
Fig.8b shows the SWOT and PEST analysis which objectively provide the critical points, which need to be resolved, and the strengths of the city of Albisola. These points therefore respectively constitute the objectives that were set during the design phase and the aspects to be enhanced.
Participation in this experience is useful to identify where to route cycle and pedestrian paths and to evaluate new proposals to improve tourism while also enhancing the hinterland.
Having developed the cognitive and analytical framework, we moved on to the intervention planning phase. Even in the latter case, the master plans considered numerous aspects which, on a methodological level, were identified as key to sustainable urban regeneration.
The territory of Albisola finds itself being divided into sectoral areas, one of the main purposes of the project is to connect the space, and above all the community that lives there. Mobility, sport, tourism and culture promoting sea, mountains and ceramic tradition are the key elements.



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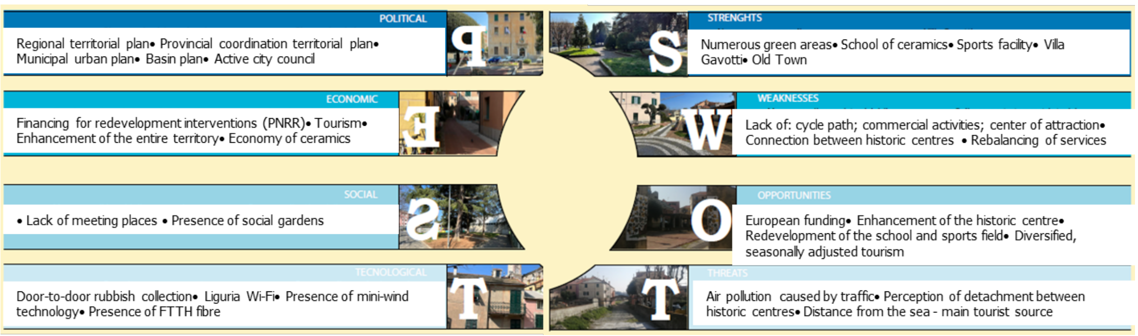

(b)

Fig.8 Case study Albisola Superiore (SV): (a) Knowledge Phase: are under study inspection and mobility systems; (b) Analysis phase: PEST and SWOT analysis

The project rethinks Albisola mobility in terms of greater sustainability and with the aim of improving the quality of life. To do this, the chosen strategy hinges on widespread interventions (redesign of Corso Mazzini and the cycle-pedestrian paths of the entire municipal area), and on specific interventions (station area and area of the Roman archaeological ruins as the main hubs of the city). The new square can represent the fulcrum; the starting and arrival point of the routes that branch out across the area, from the hinterland, passing through the residential neighborhood full of commercial activities, reaching the seaside promenade. Then there is the historic center of Albisola Superiore which has great potential, both cultural, such as the proximity to Villa Gavotti, and in terms of services, such as the sports center and trekking routes nearby, attractions that would guarantee sports tourism present throughout the period of the year.

The projects presented paid great attention to the issue of mobility. A bike-sharing service and new cycle-pedestrian routes have been planned both to reach the sea and to discover the hills and historical and monumental sites present. Separate cycle paths (from cars and pedestrians) have been defined for greater safety and specific studies on roundabouts have been developed. Special attention has been paid to the concept of accessibility and the reduction of architectural barriers to make the territory accessible to all. In-depth studies were developed on the characteristics of new cycle and pedestrian routes, signposting, materials and junctions at, for example, accesses to bathing establishments. In addition to the legally required road signs, since ceramics are a typical product, specific tiles were designed to be placed along the route to characterise the route and make it an identity element.

During the design phase, particular attention was paid to the proposal of specific materials for safety purposes. Safety and reduction of road accidents. In this regard, various materials are proposed to distinguish the road organization and therefore to separate the different flows and routes of means of transport. But, given the

proximity of the Sansobbia river, materials and technologies capable of improving drainage have also been identified, to mitigate the risks of flooding.
To assess the economic feasibility of the projects, the calls relating to the mobility of the National Recovery and Resilience Plan (*Piano Nazionale di Ripresa e Resilienza*, NRRP) were analysed. The projects also considered the guidelines for participating in the NRRP calls for proposals in order to possibly be eligible for application by the municipal administration and thus realised.
Fig.9 shows some key aspects applied in the urban planning projects created for the Albisola Superiore case study.

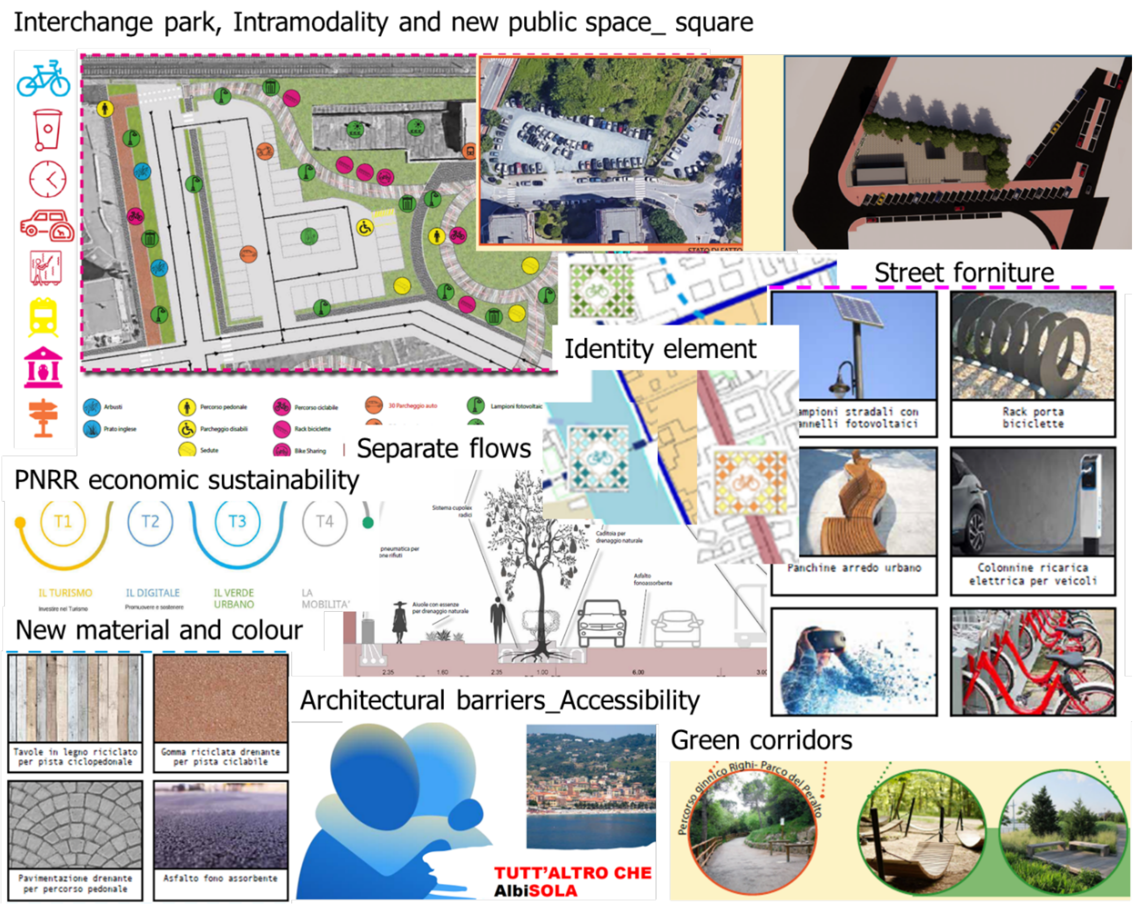

Fig.9 Case study Albisola Superiore (SV): key aspects applied

4. Conclusion

Mobility, participation and sustainable regeneration represent fundamental themes for our cities and were the key themes considered in the urban planning projects presented and implemented as part of the university courses in collaboration with the public administrations of the Ligurian Region.
To enhance and summarize how the key aspects defined at the approach level were applied in the three cases illustrated, some objectives achieved in the three urban projects are reported (Tab.1).
From the table it can be seen that in the proposed urban planning projects the synergy of the different keywords is essential.
An innovative aspect that has emerged in urban planning projects is that of resilience, understood as the ability to adapt urban space to the needs of the population (resident and temporary) which also takes into account the needs at different times of the same day. This last aspect therefore underlines the importance of temporality in urban choices.

<table>
<tr><th>Key aspects considered</th><th>Prà-Palmaro</th><th>Busalla</th><th>Albisola superiore</th></tr>
<tr><td>Intramodality</td><td>Creation of an intermodal hub between train, bus, bicycle and on foot, also with the creation of specific safe parking areas for bicycles and the possibility of a bike-sharing service</td><td>Creation of an intermodal hub between train, bus, bike and on foot, also with the creation of a specific interchange car park (useful for residents of the nearby valleys), safe parking areas for bikes and the possibility of a bike and car service sharing</td><td>Creation of an intermodal hub between train, bus, bike and foot, also with the creation of a specific interchange car park (useful for those reaching the station by car), safe parking areas for bikes and the possibility of a bike and car sharing.</td></tr>
<tr><td>Use of sustainable meas_ non-polluting vehicles</td><td colspan="3">In the experiences presented to plan a good transport system, new roads for cars are not proposed, but rather the possibility is given to choose the means of transport best suited to their needs, encouraging the use of non-polluting vehicles as much as possible, favouring a reduction in traffic and promoting a culture of sustainability applied to mobility.</td></tr>
<tr><td>Bike-sharing</td><td colspan="3" rowspan="2">Bike and E-bike sharing and Car-sharing services _of low impact vehicles_ are proposed in the three cases to support sustainable mobility also with the aim of reducing the number of vehicles, moving from a situation of ownership to one of possession temporary only when this means is truly useful.</td></tr>
<tr><td>Car-sharing</td></tr>
<tr><td>New soft mobility infrastructure and street forniture</td><td colspan="3">In all experiences, the proposal for new infrastructures, safe and exclusively dedicated to soft mobility, were included as a basic preparatory element for the use of these means. New and sustainable street furniture (canopies with solar panels and moss-covered panels) useful for the production of energy from alternative sources are also planned; improvement of liveability and air quality; creation of identity elements of characterization of the path.</td></tr>
<tr><td>New material and colour for road surface</td><td>Creation of separate flows between the different means of transport</td><td>Different materials and colours to distinguish road organization and for realized an identity element. Improvement of safety and reduction of accidents.</td><td>Different materials to distinguish road organization and improvement of drainage. This for reduction of accident and flood risks</td></tr>
<tr><td>Co-design process</td><td>Creation of a working group between technicians and representatives of the bodies involved in the area: Port Authority, RFI, Autostrade,... as well as Administration, UniGe and the population through the Associations.
Furthermore, involvement of the inhabitants through public discussion events and ultimately in the choice of the project and the winning ideas (creation of an opinion poll jury) which were chosen and explored in depth to be presented in the Pinqua.</td><td>Initially collaboration between the municipal administration and UniGe. Population involved through questionnaire and specific interviews carried out during the inspections to find out both the opportunities and the needs, in terms of lack of services/activities, that the different activity groups have shown. Final closing event open to all as an opportunity to inform and get feedback on the effectiveness and feasibility of what was proposed.</td><td></td></tr>
<tr><td>Regeneration effects</td><td>Thanks to the reorganization of sustainable mobility, a strip between the town and the port has been regenerated. A cycle-pedestrian path has been inserted, the area has been better connected to the neighborhood and an urban space has been created that can be used by both residents and tourists</td><td>Thanks to the reorganization of sustainable mobility in place of an asphalted area without a clear intended use, a green area is created crossed by soft mobility paths which make it safer to travel along the busiest street (Via V. Veneto) with significant consequences in terms of reducing traffic, pollution and noise.</td><td>Thanks to the reorganization of sustainable mobility, a public square and several green corridors have been created which, in addition to making walking the busiest streets safer (Viale Mazzini), has impacts in terms of reducing noise, pollution, heat and traffic.</td></tr>
</table>

Tab.1 Comparison between the key aspects of the three case studies

The urban project is dynamic, it is not static. This consideration underlies the concept of temporal urbanism and a new vision for designing and planning our cities. Thanks to this approach it is possible to regenerate an urban space and adapt it to the demands of the population's needs in order to improve the quality of life of today's inhabitants and improve usability of the territory itself, also taking into account future developments.

In this context, the 4 innovation helix framework, and so, the involvement of local actors: people, university, company and administration, is indispensable for guiding society towards sustainable development according to 2030 Agenda.

The main result achieved by the research group was to initiate real collaborations, putting around a table the different actors involved with the common goal of improving the livability of our cities. Liveability which is closely linked to the improvement of mobility services and their intramodality with important repercussions on the accessibility of services. The actions undertaken for more sustainable mobility lead to a path that increases the demand for integrated services for the movement of people and goods but also the attractiveness of the area from an environmental, social, tourist and economic point of view. In all the experiences presented, mobility was the starting point for initiating processes for: improving livability and connections between the city and the port in the west part of Genoa; reducing vehicular traffic and air quality, as in the case of Busalla; and making mobility more sustainable in Albisola Superiore, also a destination for mass tourism. Sustainable mobility, on the other hand, can promote the development of new forms of tourism that are also sustainable. In the experiences illustrated, the role of the University emerged as a connector capable of collaborating together and building synergies between the various actors involved with the common objective of share their knowledge experiences and therefore bring innovations and sustainability to the area.

The objective of the experiences described has been twofold: educational on the one hand and, on the other, to serve public administrations by providing sustainable and participatory projects. In the Genoese case, this objective was also achieved in terms of implementation, through participation in the subsequently funded National Innovative Program on Housing Quality (PINQuA, *Programma Innovativo Nazionale per la Qualità dell'Abitare*) call for proposals, which led to the regeneration of Genoa's new west waterfront.

Author Contributions

Introduction, F.P.; Methodology, Application and Results, F.P. and I.S; Conclusions. All authors have read and agreed to the published version of the manuscript.

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Image Sources

Fig.1: "Urban Sustainable project: key aspects", is an elaboration of the authors;

Fig.2: "A sustainable participatory mobility approach";
Fig.3: "Case studies in Ligurian Region", is an elaboration of the authors;
Fig.4: "Pra'-Palmaro Case study", is an elaboration of the authors;
Fig.5: "Case study Pra'-Palmaro (Ge): key aspects applied", is an elaboration of the authors;
Fig.6: "Busalla Case study", is an elaboration of the authors;
Fig.7: "Case study Busalla (Ge): key aspects applied", is an elaboration of the authors;
Fig.8: "Case study Albisola Superiore (SV)", is an elaboration of the authors;
Fig.9: "Case study Albisola Superiore (SV): key aspects applied", is an elaboration of the authors.

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Urban and transport planning integration. A case study in a mid-size city in Italy

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Abstract

Integrating urban and transport planning requires a well-defined approach structured across various planning and strategic levels. This emphasizes the necessity to explore the matter within the frameworks of territorial government processes. The paper aims to address the issue by examining the case of the city of Brescia, Lombardy, a mid-size city which is pioneer in Italy in the development of innovative transport systems. Brescia is equipped with a metro line and is on the final stages of in the design of the new tram line "T2 Pendolina-Fiera". The paper is developed as follow: (1) significance of the integration between urban and transport planning; (2) narration of precedents where Brescia has been at the forefront in this domain; (3) reconstruction of administrative steps that led to the design of the tram; (4) assessment of the role of the new tram line in the urban context; (5) final considerations. The research verified that it was possible for a medium size Italian city to apply the desired integrated approach, as well as the effectiveness of the local planning tool in Lombardy region (the PGT) to hold together strategic and design layers to target such goal.

Keywords

Urban planning; Transport planning; Public transport stop; Mid-size city; Tram.

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1. Integration of urban and transportation planning for sustainable cities

1.1 The crucial role of public transportation stops

The integration of transport and urban planning has long been recognized as crucial for sustainable development (Bertolini et al., 2005). Achieving climate neutrality objectives through strategies focused on mobility in urban areas is an emerging topic in the international debate (Pezzagno & Richiedei, 2022). Such awareness has been simultaneously accompanied, in the field of transportation, from a progressive focus shift from mobility planning to accessibility planning (Handy, 2002). This transition reflects the acknowledgment that the ultimate goal of transportation systems is not merely to facilitate movement but to ensure access for individuals (Handy, 2020), as much that accessibility concept has taken the place of mobility in the contemporary literature (for a review see Guida & Caglioni, 2020). This new paradigm emerged as contemporary cities face challenges such us rising motorization and urban sprawl (Cervero, 2001). The surge in the demand for (especially private motorized) mobility can be attributed to changes in habits which have led, as a result, to changes in the temporal organization of human activities and consequently, to changes in transportation behaviour. Many authors recognize time barriers as barriers to accessing public transportation and thus their use (see for example Ahsan et al., 2023; Curl, 2013; Ollson et al., 2021). In fact, nowadays it's very common to organize personal days through a multi-purpose trip, such as accompanying a child to school before heading to work. This topic is particularly relevant in Italy, where an increase in demand for mobility is observable despite a demographic decline (ISFORT, 2021).

Careful integration of urban and transport planning is essential to minimise car dependency and rationalise travel. A critical aspect of this integration is the location and design of public transport stops, which is shared by both disciplines. The stop is a crucial element of a transport network, being the interface between the user and the transport system (Maternini & Foini, 2009), but it is also an element of public space (Vitale Brovarone, 2021). Moreover, the location of a public transport stop is a decision that involves very relevant urban planning issues, such as the structure of the settlement and the location of attractor poles (Tira, 2011). Its correct insertion in the urban context can have positive effects both in terms of transport and urban planning, establishing a direct correlation between public transport accessibility and public transport attractiveness (Guglielmetti Mugion et al., 2018). In order to increase attractiveness, accessibility must be geared towards as many modes of transport as possible, with particular attention to vulnerable users such as children and the elderly (Tiboni & Rossetti, 2012). To make this possible, the public space must be appropriately redesigned, subtracting the space dedicated to private cars (Boglietti & Tiboni, 2022). The urban regeneration processes that take place in places already served by public transport must also aim to improve the walkability of the area (Carra et al., 2022). Designing a public transport system to reduce car dependency in cities requires consideration of both transport and urban planning factors. This integrated approach not only benefits transport efficiency, but also addresses urban planning concerns (Spadaro et al., 2023). Research shows a link between public transport accessibility and social inclusion, highlighting the importance of this integration in promoting an equitable urban environment (Mackett & Thoreau, 2015).

1.2 Three approaches to the integration of urban and transportation planning

Tira and Lombardi (2009) outline three approaches by which this integration can take place: by optimizing existing routes; by creating new routes; and by developing neighborhoods based on Transit Oriented Development (TOD) principles. In all three approaches, the stop is a crucial topic. In the first case, the issue is the rethinking of existing stops, in relation to their context. In the second case, it is important to locate the stops in the most appropriate places. In the third case, the design of the stop is inseparable by the design of the neighborhood that will be built around and will use it. The aim of this paper is to understand whether this integrated approach has been successfully applied in the Municipality of Brescia, a city of

198,617 inhabitants (DEMO.ISTAT, 2023) in Lombardy Region, Italy. According to the different quantitative criteria of the Union of Italian Municipalities (Tortorella, 2008), the European Union (OECD, 2022) and the OECD (OECD, 2012 & 2024), Brescia is considered a medium-sized city. In the Italian context, Brescia is recognized as a best practice in various public service sectors including urban waste management (Di Vita, 2020) and public transport, boasting the fourth highest public transport capacity among Italian cities (Euromobility, 2023). Brescia has indeed implemented significant transport projects over recent years, including the high mobility bus line "LAM" in 2004, the development of the Sanpolino TOD district in 2008, and the opening of an automatic light metro line in 2013. Additionally, a new tram line project (known as “T2”) is currently in the final design phase. These projects align with the three approaches outlined by Tira and Lombardi. The research employs both qualitative and quantitative methodologies, involving narrative analysis of project histories and GIS-based evaluation of existing and future transport routes in relation to the urban context. Data for the first research were sourced from documentation available on the website of the Municipality of Brescia and local publications, while data for the second research has been obtained from the Lombardy Region Geoportal and ISTAT websites.

2. Three transport projects in Brescia: a critical review

2.1 Optimization of existing lines: the High Mobility Line “LAM” 1

An example of the optimization of existing lines in Brescia is the High Mobility Lines (LAM, Linee ad Alta Mobilità) project, which combined the upgrading of important urban areas with a radical renovation of the public transport system. Launched in Brescia in the late 1990s and early 2000s, the LAM project involved the transformation of three local public transport lines (D, E, G) (Belotti & Baldoli, 1999) into three main lines (renamed 1, 2, 3), which formed the backbone of Brescia's public road transport network (Fig.1).

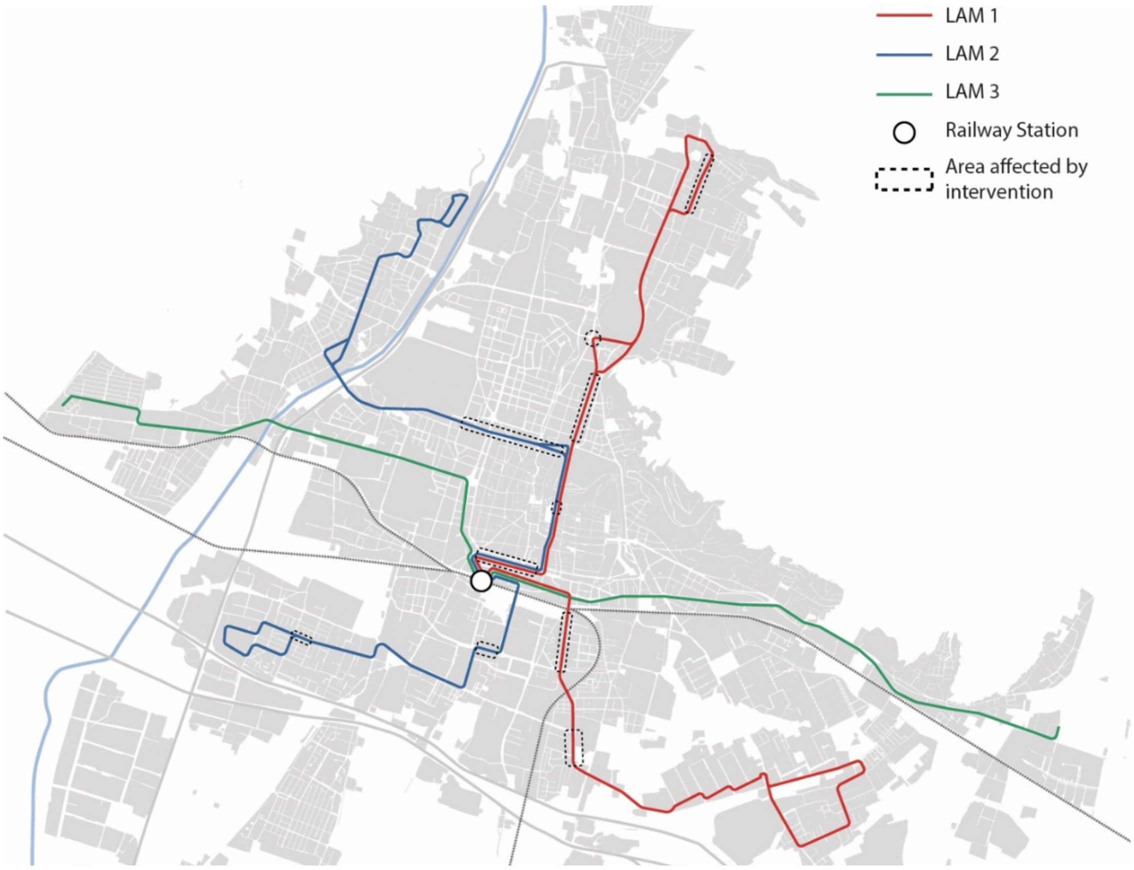


Fig.1 The three LAM lines originally planned in Brescia

The project aimed to distinguish these three lines from other bus routes, both in terms of transport performance and in terms of urban design. From a transport perspective, the LAM lines were characterized by the use of spacious 18-metre buses, as opposed to the standard 12-metre buses, and by high frequencies up to 12 vehicles per hour. In terms of urban design, the streets served by the LAM routes were slated for specific public space reorganization. These interventions, which lasted between 2004 and 2008, did not only concern aspects strictly relate to the vehicle's mobility such as the creation of bus dedicated lanes, but they also concerned the redevelopment of public space with new flooring and street furniture. The last aspect was perhaps the most relevant. The use, along the roads crossed by LAM buses, of street furniture elements with a coordinated design, guaranteed visibility and recognition of the lines themselves. For this reason, the design of the public spaces crossed by the Lam and all the waiting shelters was entrusted to the Italo Rota and Partner studio. However, the implementation of the project entailed many critical issues, referred first to the flooring, which was considered noisy and continually being restored (ANCE Brescia, 2004).

Fig.2 A LAM stop in Cremona Street

Eventually, a change in the political administration in 2008 led to the abandonment of the project: at that point ten public spaces were redeveloped, along the routes of the lines 1 and 2, but only the first line was activated with the transport standards initially requested. Line 2 effectively remained a normal bus line, as did line 3. Nevertheless, the projects had positive effects, even if partial, both in terms of transport and urban design aspects. On the one hand, between 2002 and 2008 there was a 37% increase in local public transport users (Comune di Brescia, 2018c, p. 24). On the other hand, contexts previously characterized by a poor public environment such as Crocifissa di Rosa Street and Cremona Street have been redesigned (Fig.2). The last chapter of the LAM story definitively occurred in March 2013: with the opening of the new metro line, which partly overlapped the route of LAM 1, that line was finally abolished (Galesi, 2013).

2.2 Creation of a new line: the automatic light metro

The automatic light metro line constitutes the second example in this brief overview. The placement of stops, a pivotal aspect as previously mentioned (section 1.1), assumes an even more significant role when dealing with the construction of a substantial infrastructure like a metro line. The history of the Brescia metro project is intricately tied to the positioning of its stops and urban planning decisions made by the municipal administration since the early 20th century.

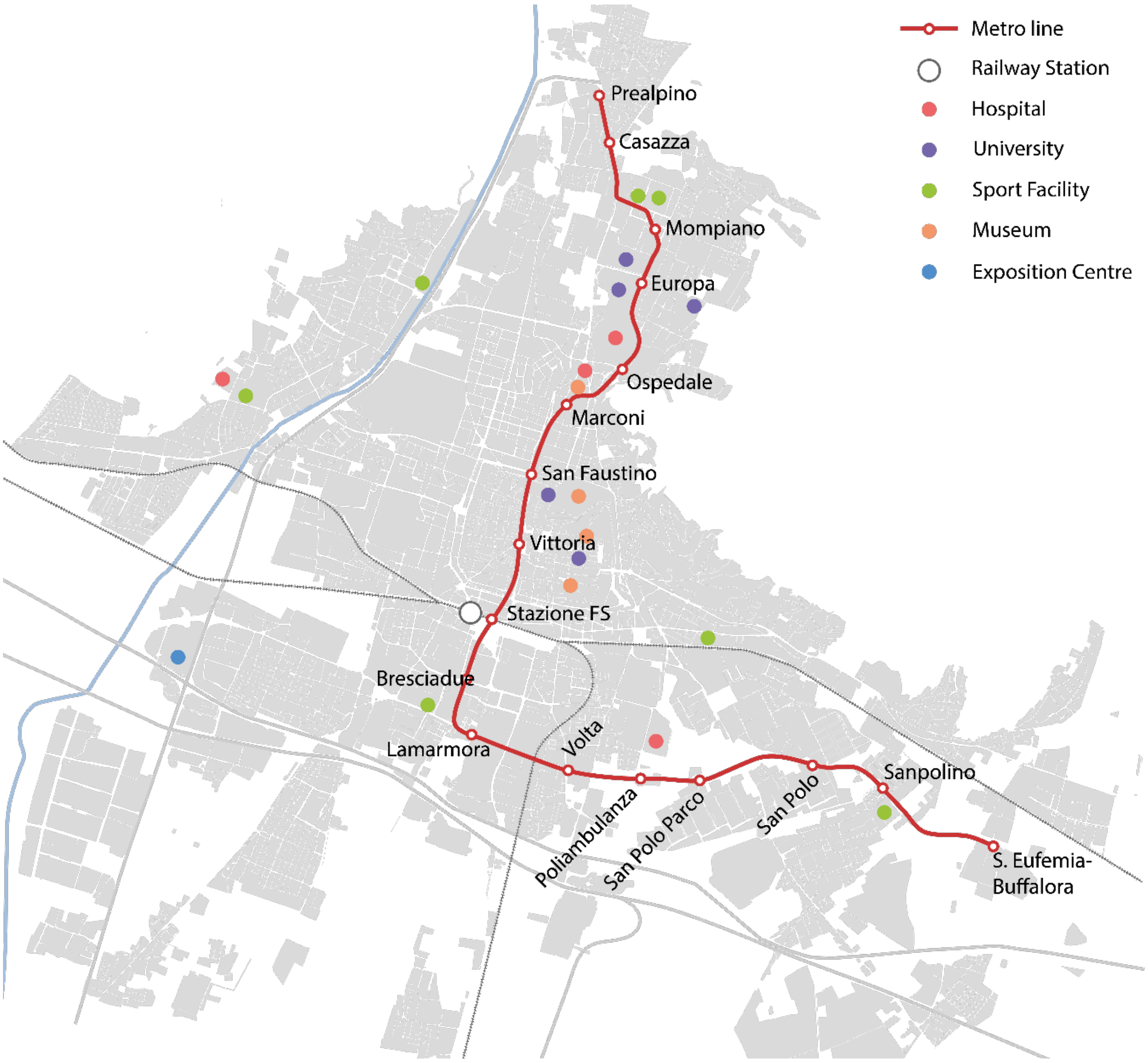


Fig.3 The metro line of Brescia in relationship with the majors' urban polarities

The concept of introducing an underground metro line to the city took shape in 1985, envisioning the creation of an automatic shuttle to connect the then-under-construction Brescia Due business centre with the railway station and the historic centre (Zanirato, 2010). Over the subsequent two years, this concept underwent further development, progressively extending the route to encompass key destinations across the city. To the north of the historic centre, the route was extended to include significant sites such as the main city hospital, the university, and the football stadium. South of the Brescia Due district, it was extended to densely populated neighbourhoods like Lamarmora and Volta, along with the large public housing district of San Polo. Following the completion of this design phase, the initial shuttle evolved into an automatic light metro. It resulted a 13-kilometer line connecting nearly all major urban attractions (Fig.3), inaugurated in 2013 after works that lasted ten years ("La nuova metropolitana di Brescia", 2013).

The design of the metro was therefore supported by two considerations linked to urban planning domain. The first is the optimal localization of the main attractor poles, arranged along a single route which has made it possible to connect (almost) all of them with a single rapid mass transit line. The second is the design of the Brescia Due business centre, which gave the first impetus to the metro project. Such aspects are linked to morphological factors of the city of Brescia which have influenced its urban planning choices (Fusi, 2023). The expansion of Brescia was in fact limited by the presence of Mount Maddalena to the east, the Cidneo hill to the north, and starting from the 19th century by the railway to the south. For millennia, the city gradually developed along the east-west direction, along the ancient road that connects Milan with Verona. A series of urban planning decision then shifted the developing axis to the north-south orientation: the opening of the tunnel under Cidneo hill and the viaduct over the railway opened the possibility of developing the plains located to the north and the south. This met the need of new large urban facilities, such as the hospital and the stadium, that has been located north of the Cidneo hill, driving a further development of the area. The area south of the railway was instead designated, starting from the 1961 PRG, to host the city's new business district: a new centre opposed to the old one, beyond the railway, to decongest the historic city. Idea then developed between the 80s and 90s through specific masterplans[1]. However, the modernist idea of a new city separated from the old city soon clashed with the need to make it easily accessible with the railway station and with that same historic centre, which was considered obsolete.

The integration of urban and transport planning criteria is evident when examining the placement of the Brescia metro stops. Several stops are strategically positioned to effectively serve the mentioned urban polarities. For instance, the Ospedale station is precisely situated in front of the main entrance of the city's largest hospital, while the Europa station is in proximity to the university. On the other hand, stops serving purely residential areas are strategically located at pre-existing communal spaces. This is the case of the Mompiano station in Kossuth Square, the life centre of the working class Villaggio Valotti district. Further examples include the San Polo and San Polo Parco stations, located near two multifunctional centres in the San Polo neighbourhood. Thus, the metro stops not only fulfil the purpose of serving certain functions or populations but contribute to reinforcing already established meeting and service points.

2.3 Transit Oriented Development: the Sanpolino neighbourhood

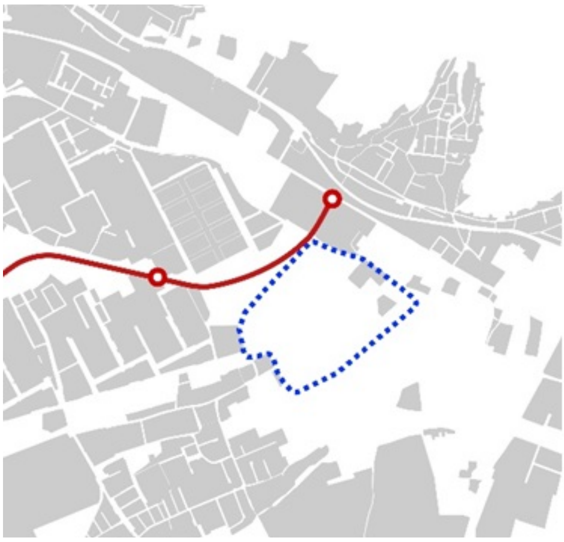
A TOD is "mixed-use community that encourages people to live near transit services" (Still, 2002, as cited in Carlton, 2009, p. 1). This approach has experienced a flourishing period, especially in the post-war period and since the 1990s (Papa & Bertolini, 2015). It has been applied mainly in large metropolitan areas in Europe and North America (Tira & Lombardi, 2009), but also in low- and middle-income countries (World Bank Group, 2021). In the context of Brescia, the district that comes closest to the principles of Transit Oriented Development is the Sanpolino district, located in the south-eastern periphery of the city: a district that, at the end of the 1990s, was involved in two different projects, the metro line and a new public residential district. The metro line was to end near the S. Eufemia locality, while the new district, Sanpolino,

[1] Specifically, Brescia Due has been developed through a *Piano Particolareggiato*, a planning tool provided by Italian urban planning law to implement large private urban interventions with public input and coordination.

was designed by the urban planner Bernardo Secchi on behalf of the city council. The district was conceived as a PEEP[2] area to extend the large San Polo public housing estate.

While the metro project received the first state's funds in 1995, the first Sanpolino masterplan was approved in 1998. The destiny of the two project intersects in 2000: on one hand, the environmental impact assessment prescribes to move the metro depot further east. On the other hand, the Sanpolino masterplan had to be modified to meet prescription by Lombardy region who asked to increase the density. Consequently, the development of the neighbourhood parallelled the development of the metro, producing a commendable example of Transport Oriented Development (Tiboni & Rossetti, 2013). The entire neighbourhood falls within a 600-metre radius from the metro stop, devoid of functions necessitating exclusive car access. The area with the highest population density is positioned in close proximity to the station, fostering numerous neighbourhood activities and forming a genuine hub of community life. According to a survey conducted by Brescia Mobilità in 2015, the Sanpolino station is more used than the two stations located in the much bigger and populated San Polo neighbourhood (Comune di Brescia, 2018a)

However, the Sanpolino overall density is not comparable to that of TOD applications found in large North American cities (Tiboni & Rossetti, 2013). In addition, the district remained partly unfinished, with some areas originally planned that were never developed, and despite being more used by others, the metro stop remains one of the less used of the entire line, ranking only in thirteenth place. To tackle these challenges, the 2016 PGT envisioned the implementation of new city-scale services and facilities in the Sanpolino area (Comune di Brescia, 2016, p. 97). This prediction materialized with the construction of an athletics track and a gym for indoor artistic gymnastics in the undeveloped areas. The objective of these interventions is to introduce city-scale functions, leveraging the accessibility facilitated by the metro station, and infusing vitality into the neighbourhood.


(a)

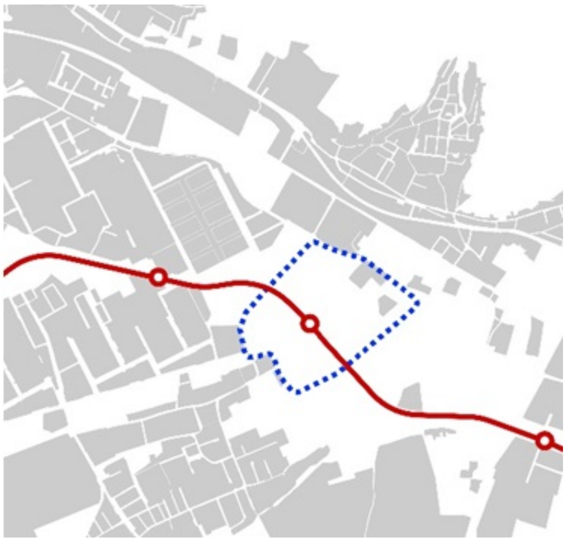

(b)

Fig.4 (a) The original metro project. (b) The definitive metro project. Sanpolino's boundaries are marked by the blue dotted line

3. The return of the tram in the Brescia's streets

3.1 Setting the strategy: the 2016 Territorial Government Plan (PGT)

Over the past two decades, the city of Brescia has experimented with three different approaches to integrating transport and urban planning. The LAM project involved rethinking public spaces, while the light

[2] *Piano per l'Edilizia Economica e Popolare*, a planning tool provided by Italian urban planning law to develop public housing districts.

metro line route is the result of decades of urban planning decisions. The Sanpolino TOD, on the other hand, is the result of merging two independent public projects. Nevertheless, a more comprehensive coordination was achieved in 2013 and 2014, when the new PGT (8 October 2013) and SUMP (16 December 2014) were formally launched. The PGT (Piano di Governo del Territorio, or Territorial Government Plan) is the instrument that defines the policies and regulations for land use and development in a given municipality in the Lombardy region.

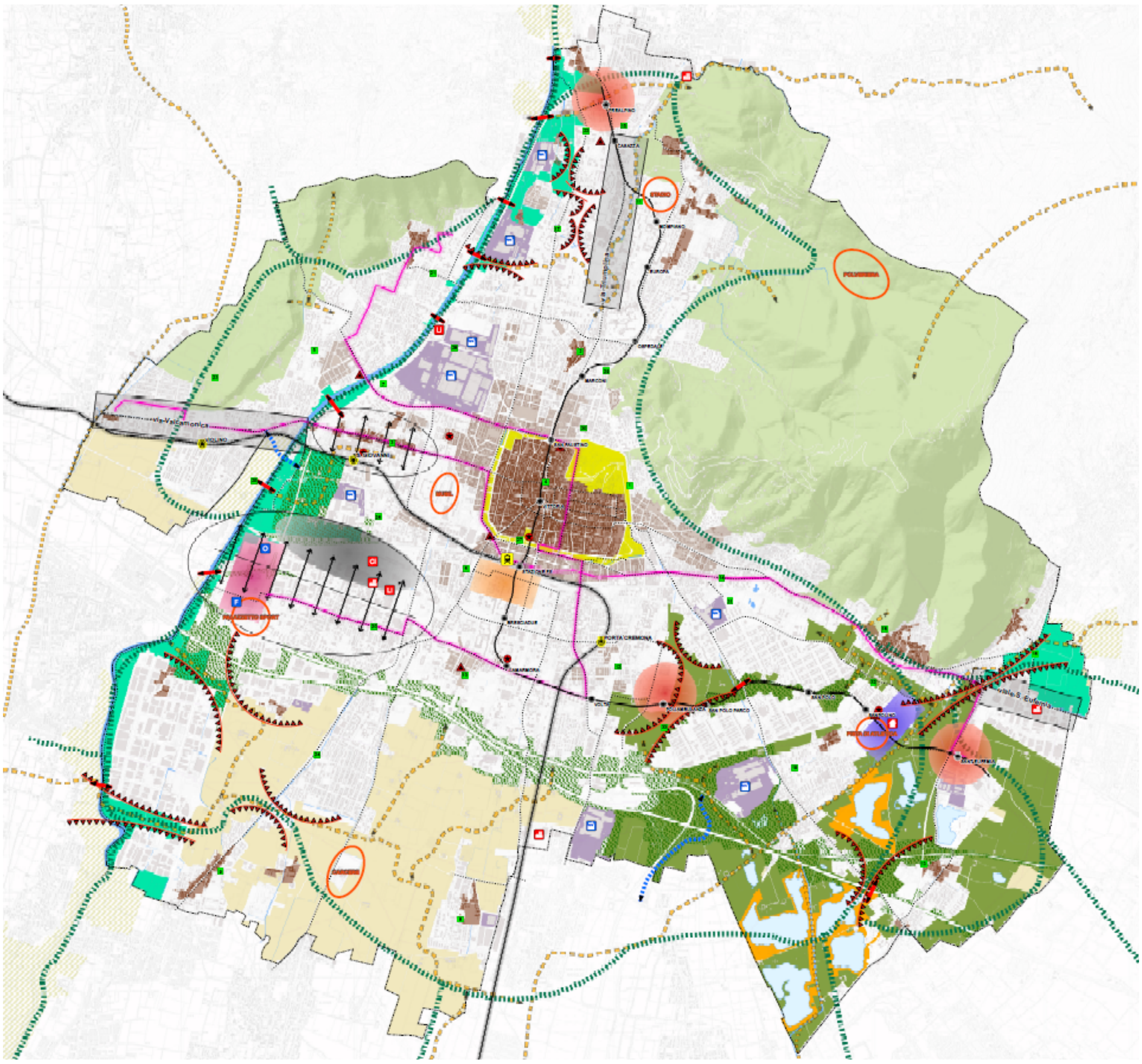


Fig.5 The Document Plan (Documento di Piano) of the Brescia 2016 PGT, which constitute the strategic element of the PGT. The lines of force are the two in purple

With the aim of improving the quality of life in Brescia (Comune di Brescia, 2016), a general variant of the PGT was approved in 2016. The three strategic pillars that support this intention are "starting from the unbuilt" (protection of non-urbanised areas), "renewing and redeveloping the already urbanised territory" (renewal of the already urbanised territory) and "accessibility as a strategy for a friendly city" (offering competitive public transport). These pillars are linked throughout by the theme of sustainability. Based on these three themes, the PGT presents a series of actions included in the document plan (Fig.5), one of which is the designation of two "lines of force" for public transport to cover the regions not served by the metro:

"The new overall network will have to represent a rapid, direct and efficient system, which identifies high-performance services along the lines of greatest traffic and potential demand external to the metro corridor.

(...) For the corridors concerned (...) of the lines of force, the increase in transit frequencies will necessarily have to be accompanied by a planning of technological and infrastructural interventions aimed at significantly increasing the regularity and commercial speed of the service offer. In particular, (…) taking up the consolidated itinerary represented by the current bus lines 2 and 3, it highlights the opportunity to achieve a further development of these east-west crossing services of the city through the possible use of innovative guided systems (bus-ways, tramways…)" (Comune di Brescia, 2016, p. 86).

The PGT acknowledges the need for better public transport in areas not served by the metro, and therefore identifies two potential corridors to upgrade - the existing bus lines 2 and 3 - and proposes the use of two technologies: the bus rapid transit and tramway.

3.2 Addressing the topic: the 2018 Sustainable Urban Mobility Plan (SUMP)

After the PGT established the theme, the SUMP, which was approved by the Brescia municipality in 2018. The SUMP objectives align perfectly with the PGT pillar "accessibility as a strategy for a friendly city" and were established in accordance with the municipal council's directive. These include goals like reducing the danger of an accident, developing shared mobility solutions, enhancing the quality of public transportation, and integrating the transportation system. Based on these goals, the SUMP compiled several potential courses of action into three scenarios (Fig.6), named B, T and M (Comune di Brescia, 2018b).

In Scenario B, three public transport lines (designated B2, B3 and B4) are implemented, modelled on the city's former LAM line, with separate lanes and traffic light priority. Line B4 is a completely new design, while lines B2 and B3 largely follow the 'lines of force' defined in the PGT, i.e. the current bus lines 2 and 3. According to the SUMP, these two routes account for 25% of all passengers on the city bus network, making them the most heavily used.

The Scenario T calls for the building of the bus line B4 as well as two tramway lines, designated T2 and T3. This is an improvement on scenario B, in which the two "lines of force" - as proposed by the PGT - become tramway lines.

The M scenario envisages an extension of the metro line in three directions: west to the Exhibition Centre, east to Rezzato and north to the Trompia Valley. All three hypotheses are based on concepts, plans and initiatives developed in previous years (Comune di Brescia, 2018c, p. 65), in particular those directed towards the north and west. The Provincial Territorial Coordination Plan of the Province of Brescia describes the extension to the north, and the initial idea even included a westward extension by using the Lamarmora station as an interchange stop.

All three options were then evaluated using a model developed by the research office of Brescia Mobilità, the local public transport operator (Comune di Brescia, 2018c, pp. 72, 76, 80). Comparing the results of the assessments, it is clear that the T scenario is the most effective in shifting people from private to public transport, and that the northern extension of the metro line is the most efficient (Comune di Brescia, 2018c, p. 82). Based on these considerations, a fourth scenario was created, called P, or the plan scenario, which included the new BRT line B4 (derived from the B scenario), the new tram lines T2 and T3 (derived from the T scenario), and the northern extension of the metro line (derived from the M scenario). Using the transport model, the scenario plan was evaluated and found to be more effective than the three scenarios alone. According to the model, the modal share of public transport in metropolitan areas could increase by up to 34%, carrying an estimated 65 million passengers per year (Comune di Brescia, 2018c, pp. 86-87).

The two system the SUMP provides as an integration of the metro line are not a total novelty fort the city of Brescia. The B4 line revives the LAM idea, while the T2 and T3 lines reintroduce a system that was already present in the city of Brescia between 1882 and 1949 (Robecchi, 2009). The reintroduction of the tram system in Brescia is part of a wider "tram renaissance" trend that has affected Western Europe since the 1980s and which has seen many mid-size cities rethinking the use of this mean of transport (Spinosa, 2013).

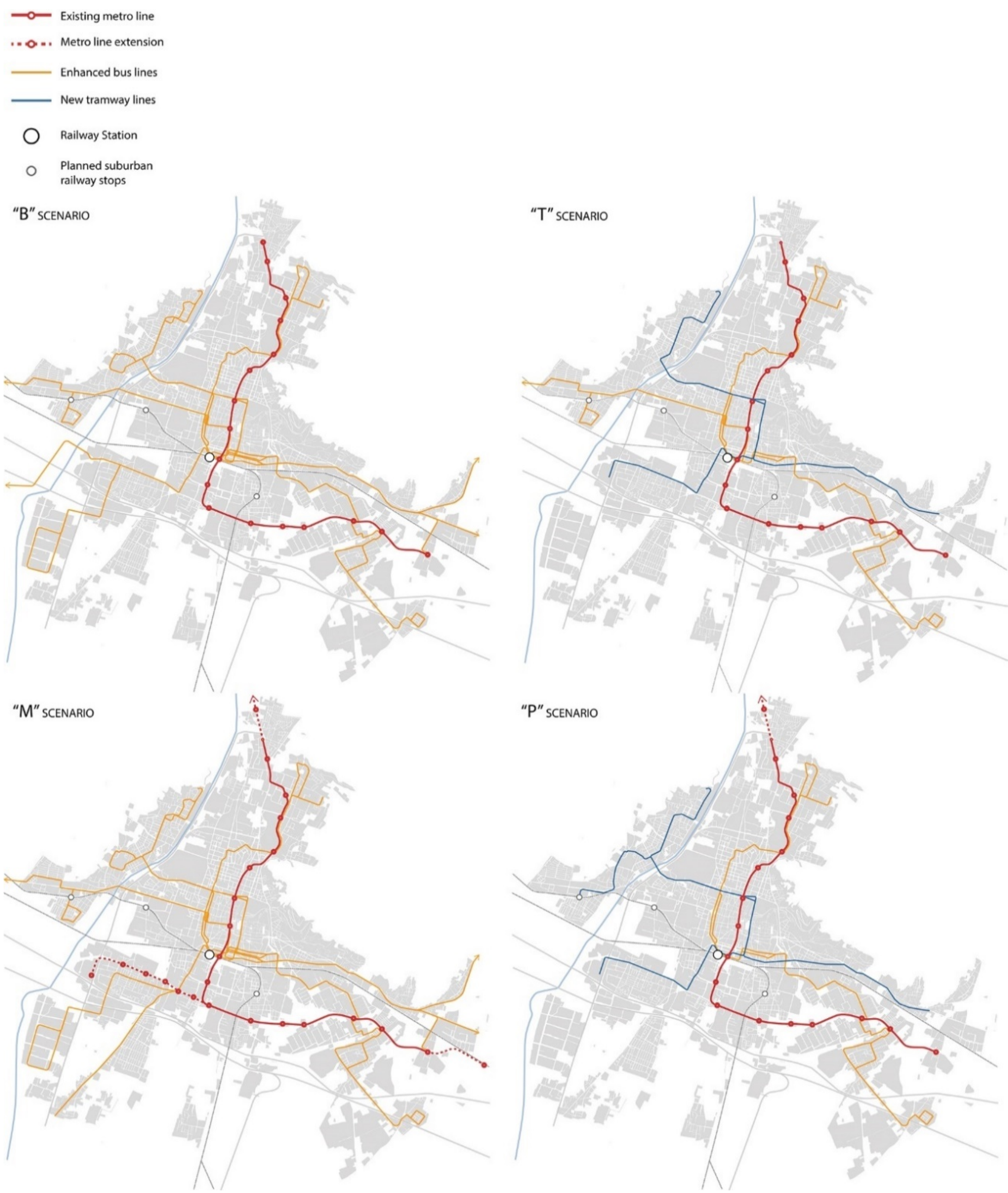


Fig.6 The four scenarios in the Brescia's SUMP

Actually, a first tram reintroduction proposal in Brescia already occurred in the 1990s and deserves a brief mention. In 1994 the municipality of Brescia relied on the consultancy of Bernardo Secchi to design the new PRG (*Piano Regolatore Generale*, General Master Plan), which was the Italian municipal urban planning tool before that Lombardy region replaced it by the PGT in 2005. At the time the municipality was detailing the metro project, but Secchi proposed instead the development of two tram lines, named 'tau' and 'lambda', thought to serve two different urban contexts. The "tau" line should link together the areas characterized by major urban polarities, while the "lambda" line should serve residential areas and schools. The interchange between the two lines was thought to take place in the areas where these two urban systems met (Secchi &

Viganò, 1998). Such plan was cancelled in 2001 by a TAR (Regional Administrative Court) ruling (Lupo & Badiani, 2009). Consequently, the tram idea was abandoned in favor of continuing the metro project.

(a)

(b)

Fig.7 (a) Brescia's historical tram network at his peak in 1935, overlapped to the current urbanized areas; (b) The tram network designed by Bernardo Secchi

3.3 Turning the strategy in action: the "T2" design process

Following the approval of the SUMP on 5 February 2018, an opportunity for implementation has arisen. As mandated by the 2018 Budget Law (Law 205/2017), the Ministry of Infrastructure and Transport launched a public tender process to allocate funds for the mass rapid transport system. This fund covered expenses such as new vehicles, the construction of trolleybus, tram and metro lines, and the renovation of existing lines. Brescia Mobilità partnered with the Italian State Railways to submit the required documents by the tender deadline of 31 December 2018 (Ferrovie dello Stato Italiane, 2018). The partnership aimed to design, build and manage two tram lines outlined in the SUMP. They proposed a project financing model with majority private investment totalling €400 million, with the aim of being operational by 2027.

In a joint effort, they conducted a feasibility study (PFTE, Progetto di Fattibilità Tecnico- Ecomica) over the following months, aligning the project with the SUMP tram lines: T2 from the Pendolina district to Expo, connecting to metro stations; and T3 from Violino to S. Eufemia metro station, sharing the central route with T2. In addition, a third line connecting Expo to S. Eufemia was proposed. The total length of the system was approximately 23 km, 35% of which was in dedicated lanes. An alternative, less costly plan proposed building only the T2 line for 11.75 kilometres. The project was submitted to the ministry on 31 December 2018, seeking €252 million, or 51% of the total funding required. The rest was expected to come from project financing. However, when the Ministry published the ranking on 18 December 2019, the project was ranked 19th and did not receive funding. This raised concerns about the sustainability of the funding. The Ministry's decision to fully fund seventeen other projects suggested a preference for state funding over public-private partnerships, contrary to Brescia's expectations.

After the rejection, the Municipality of Brescia made the decision to review the project with the aim of participating in a second tender. In fact, the 2019 budget law (Law 145/2018) allocated new funds for rapid mass transport and set new deadline for 15 January 2021. To this end, the Municipality gave a mandate to Brescia Mobilità to prepare a new feasibility project on 30 September 2020 and withdrew from the cooperation agreement with the Italian State Railways on 1 July 2020. The instance presented to the Ministry was very different from the old one.

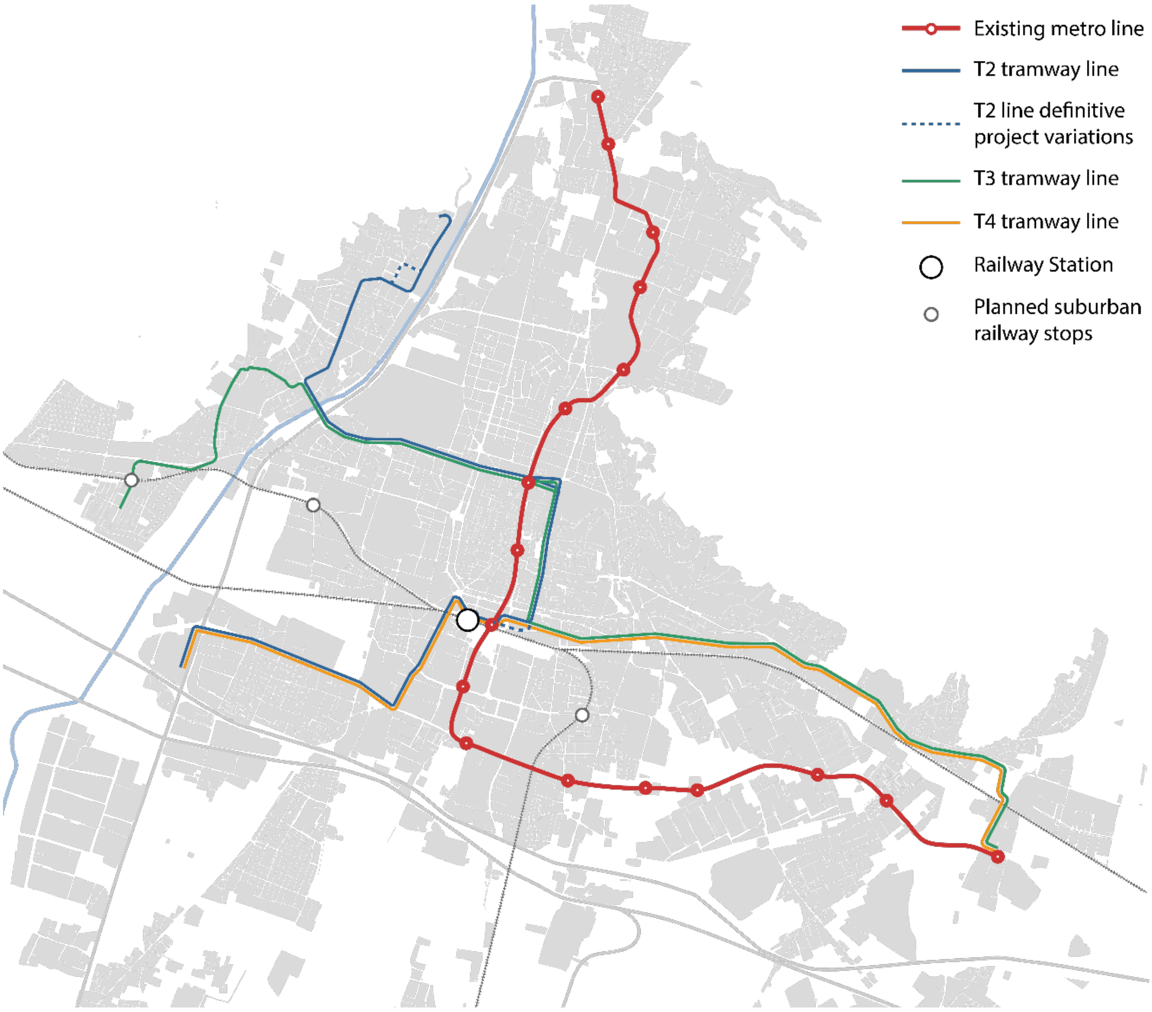


Fig.8 Brescia's tramway line projects. The T2, T3, and T4 lines were a part of the initial feasibility project, which was rejected by the ministry. Only the T2 line was included in the second feasibility project, which has been approved

Firstly, it included the T2 line alone, which had been prioritised in the SUMP. Secondly, in order to improve service efficiency and meet increased demand, the percentage of dedicated lanes was increased from 35% to 70% of the total route. Thirdly, the project funding approach was abandoned in favour of public funding for the whole project, with the Ministrial's funding request covering 99% of the projected costs. Specifically, €359 million were requested, of which 254 for rolling stock and infrastructure, 12 for safety fees, 9 for environmental monitoring, 44.7 for VAT and 39.3 for expropriation and redesign of public spaces crossed by the tram. The projected 12.4 million annual passengers by 2032 is in line with the SUMP projection, with a projected 3.3% annual reduction in private transport passengers. The expected commercial speed was 18 km/h, slightly faster than the 17 km/h of Brescia's buses and slower than the 28 km/h of the Brescia metro. The expected passenger capacity of the vehicles was 250, which is more than a 100-seater bus but less than the metro vehicles, which have a capacity of 440 passengers per vehicle. The expected frequency during peak hours was 12 vehicles/h in each direction. This is more than the current frequency of 6 vehicles/h on the main bus routes, but less than the Metro frequency of 15 vehicles/h (Comune di Brescia, 2018c).

The second instance was successful; on 22 November 2021, the Ministry issued Ministerial Decree 464/2021, allocating the full €359 million euros for the Brescia projects. To continue with the design process, on 2 February 2022, the Municipality of Brescia mandates Brescia Mobilità S.p.A. to proceed with the

development of the definitive project (Municipal council resolution 35/2022). The municipal company called for a tender which closed on 4 April 2022, that was seen as a winner the French engineering firm Systra Sotecni SPA. At the request of the municipality, Systra made two variations to the preliminary design, regarding Urago Mella neighbourhood and next to the courthouse (Comune di Brescia, 2023). On 27 February 2023, the Municipal Council appointed Brescia Mobilità as the body responsible for implementing the project and awarding contracts for the construction of the tramway (Municipal council resolution 9/2023). On 8 August 2023, the verification process of non-subject to environmental impact assessment was successfully completed (Regione Lombardia, n.d.b). On 24 August 2023, the Municipality has started the Services Conference process, which concluded on 24 October 2023 with positive outcome (Municipal Notice Board Protocol 267524/2023; Municipal Notice Board Protocol 312029/2023).
In parallel with such technical-administrative steps, the municipality updated the PGT, closing the circle of urban and transport planning integration which began with the launch of the SUMP and PGT procedures in 2013. Indeed, with the fourth PGT variant adopted on 23 January 2023 (Municipal council resolution 5/2023), the tram project has been incorporated into the urban planning instrument (Comune di Brescia, 2024). The approval of the definitive project is expected in the first half of 2024 while the entry into operation of the Pendolina-Fiera T2 line is expected in 2030 (Fatolahzadeh, 2024).

4. The T2 tram: assessment of the route with a GIS-based approach

4.1 Method and materials

As mentioned in section 1, the location of stops is critical in the design of a new public transport line and, as the case of the Brescia metro (see section 2.2) shows, it is one of the issues where urban and transport planning can work together most effectively. GIS software can be used to determine how the public transport line relates to typical aspects of urban planning - such as housing density and land use - in order to understand the level of integration between urban and transport planning. This can be done by examining the population and urban destinations served by the existing metro and the future T2 tram line.
The evaluation was conducted on the existing metro line and the future T2 tramway line. Firstly, the needed georeferenced data (shapefile format) were downloaded: land use, transit line and its stop, census sections. Census sections are from the 2011 census, the most recent available, and were downloaded from the ISTAT website together with the corresponding csv files (from the 2021 census) with the residents' data (ISTAT, n.d.). Land use data and the metro line were downloaded from the geoportal of the Lombardy region. Land uses are from the "plan forecast" (*previsioni di piano*) dataset, which contain the Ambiti_tessuto_urbano_consolidato.shp file. This file contains the field DCOD_DEST1 that classifies urbanised blocks by land use. The metro line is from the "mobility infrastructure" (*Infrastrutture della mobilità*) dataset, which contain the Rete_Metropolitana.shp and Stazioni_Metropolitana.shp file, respectively referred to the line and stop of the metros in the Lombardy region (Regione Lombardia, n.d.a)
The shape file of the future tram route was instead created from scratch, based on the definitive project general report available in the Municipality of Brescia's website. Secondly, the area of influence of the stops was determined. It was chosen to consider buffers of 800 metre for the metro and 600 for the tramway. The latter area, halfway between the catching area of a bus (400 metres) and a metro (800 metres) was chosen considering the performance expected from the tramway, halfway between those of the metro and a bus (section 3.3). Those values (400 metres for bus stops' buffers and 800 metres for metro stations' buffers) are commonly used in the public transport sector to identify the area from which the majority of transport users will access the system by walk (El-Geneidy et al., 2014). In addition, those catching areas are supported by a vast literature that sees this value as suitable for the context (a medium-sized European city) and the transport systems considered (i.e. in Moyano et al., 2023; O'sullivan & Morrall, 1996; Sarket et al.,

2020). Once the necessary data was important on GIS software, the influence area of the stops was obtained (with buffer geoprocessing tool) according to the criteria mentioned above (800 metres for the metro, 600 metres for the tram). The areas of influence were then summed up (with the dissolve geoprocessing tool) to obtain a single geometry, constituting the area of influence of the public transport line considered. The ISTAT census sections were merged with the corresponding csv files, in order to obtain geo-referenced population data.

4.2 Results

By intersecting the influence area of the tramway with the population data it appears that the tramway has the capacity to serve 80,350 people (equivalent to 41% of the population of Brescia). When the buffer is intersected with land use data, it becomes clear that the most served land destinations are residential (36.58%), particularly in the northern part of the line. Commercial (5.46%) and industrial (7.34%) uses are concentrated in the southern section (Fig.9). Public services occupy only 19.68% of the catchment area, with the Exhibition Centre being the only major urban attractor (see Fig.3, section 2.2). Applying the same procedure to the metro route, with an 800m buffer, the population served is 103,563, representing 52% of the municipality's total population. In terms of land use, in addition to the residential function (30.96%, lower than the T2 line), commercial functions and public services (23.89%, higher than the T2 line) are served, including several urban polarities (Fig.10). In order to improve the test, it could be assumed that the T2 line will be upgraded to the same rank as the metro line, effectively replacing the tram line with a second metro line. This would essentially mean that a second metro line would replace the tram line. Applying an 800-metre buffer around T2 stops would do this, indicating that the population served (93,290) would be comparable to that of the current metro. However, with the exception of the Exhibition Centre, major urban polarities would still remain unmet (Fig.11). The proposed method has some merits and some limitations. The first limits is that it consider buffers rather than isochrones. The latter tool is characterized by greater refinement (Rossetti et al., 2020) and can consider the accessibility of different means of transport (Tira et al., 2016). Thus, an improvement of the proposed method could take into account the calculation of isochrones. Secondly, it does not take into account all the data used in the transport sector (such as origin-destination matrices and benefit-cost ratios). However, since the T2 line has previously been examined from a transportation perspective using Brescia Mobilità's model, it is helpful to retrospectively examine how the tram project fits into the urban setting.

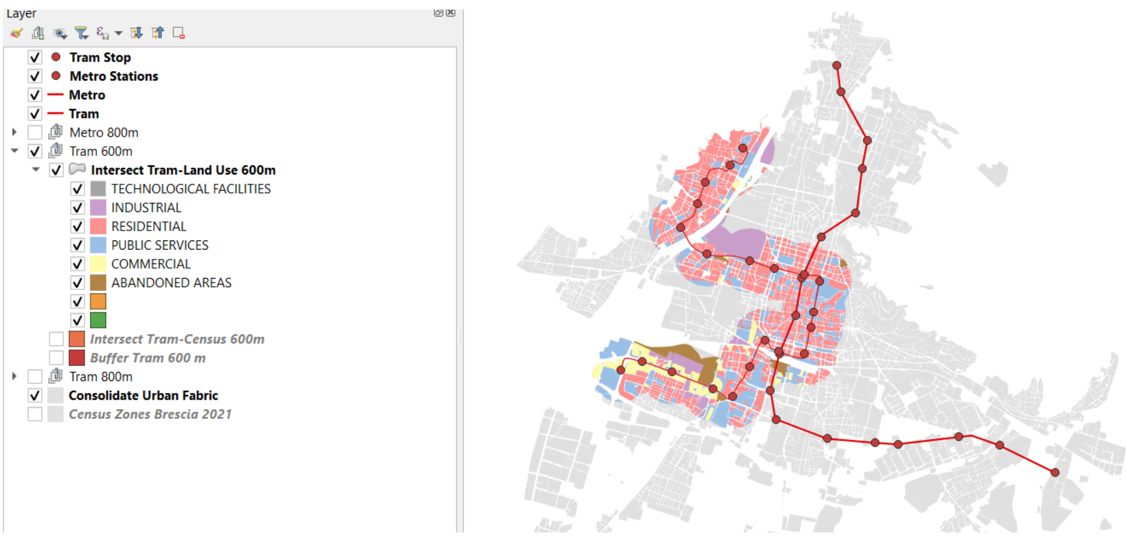


Fig.9 T2 Tram line 600 m catching area intersected with land uses

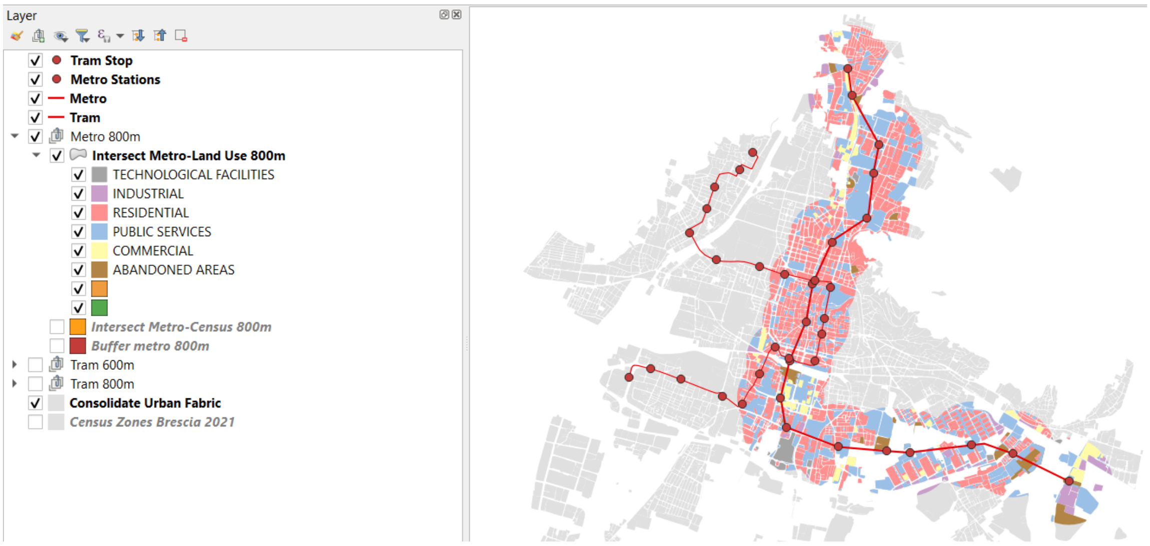


Fig.10 Metro line 800 m catching area intersected with land uses

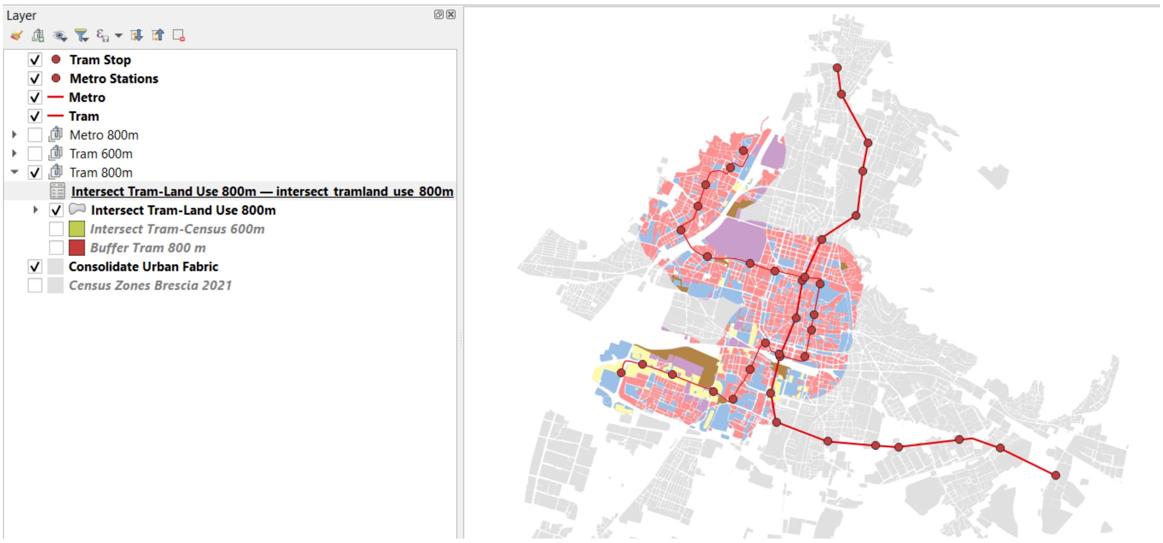


Fig.11 T2 line 800 m catching area intersected with land uses

	Line length	Population served	Pop./km	Residential	Commercial	Industrial	Public Services	Dismissed Areas	Other
Metro	13.7 km	103,563	7,559.34	30.96 %	3.35 %	2.63 %	23.89 %	3.42 %	35.75 %
T2 as tram	11.3 km	80,350	7,110.62	36.58 %	5.46 %	7.34 %	19.68 %	4.65 %	26.33 %
T2 as metro	11.3 km	93,290	8,255.00	33.58 %	4.74 %	7.38 %	19.13 %	4.65 %	30.52 %

Tab.1 Inhabitants and land uses intercepted by respective buffers

5. Final considerations: Brescia as a laboratory of integration between urban and transport planning

While in the three cases studies exposed in section 2 it is recognizable a particular attention to mobility issues, it is not clear an exemplified strategy. The idea of the metro, despite its innovativeness, was born from the desire to serve a specific city district, and only later was it included within a broader strategy to reduce the use of private cars. Furthermore, it was the urban development of the decades between 1950s and 1970s that determined its path and not vice versa. Sanpolino was not conceived from the beginning as a TOD and it is not the consequence of an intended synergy between housing and transport policies, but it is the result of a punctual union between two previously separate projects. The LAM project brought some beneficial results in terms of public space and an increase in public transport passengers but remained largely incomplete. However, this attention to the topic of mobility has outlined, project after project, a vision of a city with fewer cars, with a continuous refinement of the integration between transport and urban planning, eventually emerged in the T2 line. The tram project is indeed included in a broad strategy to improve the quality of life in the city, consistently with objective 11 of the 2030 agenda for sustainable development. A strategy expressed in the municipality's general planning tool, the PGT, and in-depth in its technical details in a sectoral tool such as the SUMP. A project that is still pending approval, and that is likely to undergo further adjustments before final approval.

From the assessment in section 4 it emerges that the two mass public transport lines in Brescia have different roles: the metro connects major urban polarities each other (as mentioned in section 2.2), whereas the tramway connects large residential areas to the city centre and the nearest metro stations. Thus, the T2 line is at a lower hierarchical level than the metro line, which justifies the use of a less performing system. The city of Brescia is developing a hierarchically complex transport system consisting of bus, tram and metro, that in Italy, only four other much larger cities - namely Rome, Milan, Turin, Naples - can boast (Spinosa, 2019).

However, despite its lower hierarchical level, the T2 that has great potential not only for the redevelopment of public spaces, but also for the regeneration of abandoned areas. In fact, the T2 catchment area involves a fair number of abandoned areas (4.65% of the total), which will increase their recovery opportunities, consistently with the aims of the PGT. These areas are located mainly along Orzinuovi Street, a road axis in the south-western periphery of the city which the PGT identifies as a "complex urban fabric" to be "subjected to functional and structural redevelopment". The tram will therefore increase the possibilities of implementing the PGT in this area. Furthermore, the T2 line is characterized by a particular coverage of industrial areas (7.34% of the buffer) which are almost completely uncovered by the metro. This coverage not only allows to better serve large traffic attractors, but also provides a better recovery opportunity in the event of decommissioning of these production plants. Possible future recovery projects for these areas will not be able to avoid considering the presence of an important infrastructure such as the tram, opening the future to new opportunities for integration between urban design and transport planning in the city of Brescia.

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Image Sources

Fig.1: Elaborations by the authors from a brochure issued by ASM, now Brescia Trasporti

Fig.2: Retrieved from: https://www.professionearchitetto.it/mostre/notizie/2645/Italo-Rota-Linee-ad-Alta-Mobilita. (Accessed on 24-10-2023)

Fig.3: Elaborations by the authors

Fig.4: Elaborations by the authors

Fig.5: Comune di Brescia, (2016). Piano di Governo del Territorio, Documento di Piano, V-DP02 Carta delle strategie. Retrieved from: https://www.comune.brescia.it/aree-tematiche/urbanistica/piano-di-governo-del-territorio/documento-di-piano-pgt-2016 (Accessed 11-3-2023)

Fig.6: Elaborations by the authors from Comune di Brescia, (2018). Piano Urbano della Mobilità Sostenibile - Allegato L: Scenari di piano. Retrieved from: https://www.comune.brescia.it/sites/default/files/imported/servizi/mobilitaetraffico/settmob/docPianificazione/pums/Documents/AllegatoL_Scenari%20di%20piano%20e%20schede%20di%20progetto.pdf (Accessed on 3-11-2023)

Fig.7: Elaborations by the authors from Robecchi (2009) and Secchi & Veigano (1998)

Fig.8: Elaborations by the authors

Fig.9: Elaborations by the authors in GIS environment

Fig.10: Elaborations by the authors in GIS environment

Fig.11: Elaborations by the authors in GIS environment

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Methodologies for estimating emissions from road transport and comparison with the inventory air emissions (INEMAR). The case of Pavia Province

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Abstract
According to the actual portrait of emissions (Arpa Lombardia), it is necessary to improve the quality of life and the environment, minimizing emissions into the atmosphere from this sector, implementing specific actions by society and institutions. The population, the population density and the fragmentation of urban centres influence the demand for transport which consequently influences the quantity of emissions to which the populations are exposed. This study focuses on the area of the province of Pavia, one of the most inadequate provinces in terms of air quality in Lombardy Region comparing urban settlements, road system and emissions. Considering the 2019 emission picture from INEMAR (INventory AiR EMissions - Lombardy Region), road transport is responsible for about 13% and residential buildings for about 10 % of total CO_2 equivalent emissions in the province of Pavia. In the paper authors aim to evaluate the inter-scalar relation between Province scale and Municipality scale according to the following analysis: 1) Search regression equation between "settlements" and "pollution" 2) Search regression equation between "road soil occupancy" and "pollution". The emission data resulting from the INEMAR algorithms are compared with the land use's geographical data present on the open-source GIS cartography and on official data (ISTAT and Lombardy Region). The result should highlight in an "emission based" analysis of land use, the opportunities of integrated mobility new systems.

Keywords
Emissions; Inventory; Lombardy Region.

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1. Introduction

1.1 Study area: Pavia Province

Urban areas have developed over the time, driven by the economic success of cities (Beall & Fox, 2009). This development has led to phenomena such as increased land use and emissions from human activities, in particular production processes, residential combustion, and road transport (Droj et al., 2023; Lo & Quattrocchi, 2003). Urban areas today account for 75% of primary energy consumption and about 60% of carbon dioxide emissions: For this reason, it is increasingly important to develop sustainable intervention strategies to streamline the transport system and increase the energy efficiency of buildings that are affecting the environment (Maranzano, 2022). This study supports the implementation of quantitative analytical tools able to estimate the effects of road traffic and residential combustion in terms of emissions based on geographically detectable data. The Lombardy Region collects a large amount of geospatial data that can be processed through a geographic information software GIS such as, for example, the open-source Q-Gis.

The working assumption is that there is a relationship of close interdependence between land use and emission scenario (Babiy et al., 2003; Bashir et al., 2020; Heres et al., 2011; Hong & Shen, 2013; Janssen et al., 2008; Pezzagno & Rossini, 2015; Wen et al., 2022; Xu et al., 2016; Zimmerman et al., 2020; Zheng et al., 2017). This contribution aims to propose a method that allows to investigate the possible interrelationships between land use and human actions and their potential for CO_2eq emissions, identifying the factors that most influence these processes to outline possible intervention strategies in the perspective of mitigation of risks from climate change.

The study area is the province of Pavia, located in the Po Valley, it is one of the most disadvantaged areas in Europe from the point of view of air quality (Briganti, 2007) because of its geographical and physical characteristics: the closed geographical conformation, the poor ventilation of the area, the frequent thermal inversions and the modest mixing layer height increase the stagnation of pollutants and reduce their dispersion (Caserini et al., 2016; Quality report of the air of the province of Pavia, 2020).

The Pavia province population constitutes the 5% of the Lombard population; its 534,691 inhabitants are concentrated mostly in the cities of Pavia, Voghera and Vigevano (31% of the total). The average population density of the province of Pavia is about 184 inhabitants / sqkm and is lower than the regional average (422 inhabitants / sqkm) (ISTAT, 2022).

In this study the authors describe the state of the art of Pavia province and analyze 6 municipalities: Pavia, Vigevano and Voghera that are the 3 most populated and largest cities of the province and Belgioioso, Mede and Casteggio that are 3 municipalities characterized in having a population about 6,000 inhabitants and having a major road that cross the municipal area.

1.2 INEMAR Database

The inventories of the emissions evaluate the contribution of the various pollutants emitted from various sources and allow us to identify, for each source, the type of pollutant, the quantity emitted and the location. The Lombardy Region inventory of atmospheric emissions INEMAR of ARPA LOMBARDIA, is currently available for the year 2019. Consequently, all the data in this research is derived from this database (INEMAR, 2019). As regards point sources were used collections of already available data, such as emissions reported by companies subject to the IPPC Directive. For diffuse emissions it is not possible to obtain a direct measurement, and it is therefore necessary to estimate them starting from statistical data and appropriate emission factors according to the methodologies adopted at national (ENEA-ANPA) and international (Corinair) level (Corinair, 2019; INEMAR, 2019). In this study we consider the pollutant aggregate CO_2 equivalent since "CO_2eq" emissions represent total greenhouse gas emissions, weighted based on their contribution to the greenhouse effect. The estimated aggregate greenhouse gas emissions based on the following relation (1) (Emission factors INEMAR, 2019).

$$CO2eq. = \Sigma i\ GWPi\ x\ Ei \quad (1)$$

where:

- CO_2eq = CO_2 equivalent emissions in kt/year;
- GWPi = 'Global Warming Potential', coefficient IPCC equal to 1.000, 0.025 and 0.298 for CO_2, CH_4 and N_2O respectively;
- Ei = CO_2 emissions (in kt/year), CH_4 and N_2O (in t/year).

The Province of Pavia from 2003 (the year of which we have the first emission inventory of the Lombardy region) to 2010 saw a 30% increase in emissions from the road transport sector and subsequently saw a decrease of 23% from 2010 to 2019. INEMAR highlights that this gradual rehabilitation is a consequence of the adoption of new technologies and compliance with the regulatory provisions introduced at European and national level and the Regional Plan of interventions for air quality. Emissions from vehicular traffic decreased by an average of 19 % thanks to the renewal of the circulating fleet, also favored by the limitation of the circulation of older euro classes, and the introduction of efficient systems for dust suppression such as the particulate filter. The reduction of the sulphur content in fuels as well as the limitation of industrial emissions as part of the process of issuing Integrated Environmental Authorizations (IEA) have made a significant contribution and domestic heating has contributed to reducing harmful emissions thanks to the increased use of natural gas and energy saving interventions in buildings (Maris & Flouros, 2021).

The INEMAR database (AiR EMission INventory) contains all the data for emission estimates and execution procedures of the algorithms used for these estimates: activity indicators (e.g., fuel consumption, paint consumption, amount incinerated); emission factors; other statistical data necessary for the spatial and temporal distribution of emissions (Methodology INEMAR, 2019).

The emission factor represents the emission related to the activity unit of the source, expressed for example as the amount of pollutant emitted per unit of product processed, or as the amount of pollutant emitted per unit of fuel consumed, etc. Among the most comprehensive bibliographical sources for emission factors are reports by the US Environmental Protection Agency, and in the European context mention the emission factors collected in different versions of the EMEP/EEA Emission Inventory Guidebook, have the best features of completeness and reliability.

The objective of INEMAR's traffic module is to calculate road transport emissions from vehicle exhaust, brake, tyre and road surface wear, and fuel evaporation. The module consists of the calculation of linear traffic which is the one on large arteries and the calculation of diffuse traffic which is that in urban centers.

Linear emissions are emissions from traffic on the suburban and motorway road network and are estimated based on the number of vehicular passages on the different arcs of the network (or graph) evaluated by a traffic allocation model.

Diffuse emissions concern emissions in residential areas (for this reason also called 'urban traffic emissions'), and are estimated from fuel sales data, the composition of the registered fleet (ACI data) and the expected average annual vehicle journeys.

Emissions depend mainly on the fuel, the type of vehicle and its age, as well as driving conditions. The estimation of traffic emissions in Lombardy therefore considers the consistency of the circulating fleet and the average annual mileage of vehicles (Traffic INEMAR, 2019). In the Inemar system they are obviously considered average values for these data, but it should be remembered that a vehicle's emissions depend on its actual maintenance and running conditions. To calculate the amount of co2eq produced by a vehicle in a year, it is sufficient to multiply the distance travelled in km, by the emission factor in g/km of CO_2 of the vehicle as in the formula (2).

$$E = NxLxFE \tag{2}$$

where:

- E = emissions (t/year);
- L = average journey length per vehicle;
- N = number of circulating vehicles;
- FE = emission factor.

The objective of the heating module is to determine the energy needs for the heating of buildings for civil use and to derive the fuel consumption used for thermal needs.

The methodology included in the heating module provides an estimate of energy requirements (in GJ/year), fuel consumption (t/year) in each municipality or census section, category of year of construction, type of fuel used (methane, diesel, LPG, electricity, other, not defined, fuel oil, wood) (heating INEMAR,2019; Inventory INEMAR, 2019). For combustion processes fuel consumption is generally chosen as an activity indicator through the formula (3).

$$E = AxFEi \tag{3}$$

where:

- Ei = emission of the pollutant i (t/year);
- A = activity indicator;
- FEi = pollutant emission factor I.

2. Data and Methodology

2.1 A Multiple Regression Analysis Output

In this paper the authors have focused on the analysis of a static regression model (Berry et al., 1985; Ceylan et al., 2018; Del Giudice, 1995; Irwin, 2001; Negri, 2006; Nordio et al., 2013) between the emissions data resulting from INEMAR algorithms and the demographic and geographical data of ISTAT and derived from DBT files (Lombardy Region Geoportale). The aim is to find a relationship of dependence of emissions (dependent variable Y) on demographic and territorial factors (independent variables X) through the multiple regression model by which from several explanatory variables it is possible to make predictions on a dependent variable through a linear relation (4).

$$E = Y_\mathrm{i} = \beta_0 + \beta_1 X_{1\mathrm{i}} + \beta_2 X_{2\mathrm{i}} + \cdots + \beta_p X_{p\mathrm{i}} + \epsilon_\mathrm{i} \tag{4}$$

where:

- β_0 intercept;
- β_1 inclination of Y with respect to variable X_1 holding constant variable X_2;
- β_2 inclination of Y with respect to variable X_2 holding constant variable X_1.

The choice to use the regression method derive from a previous study that underline the total lack of correlation between land use and total emissions. The correlation was not only weak, but also negative, and this result was amazing (De Lotto et al., 2022).

2.2 Data and Results

The calculation of emissions is developed in terms of CO_2eq because, as anticipated, it represents the total emissions of greenhouse gases, weighed based on their contribution to the greenhouse effect.

For the first part of calculation the variables considered are:

- CO_2eq.tot (kt/year) = Road transport emissions of each individual municipality i as shown in Tab.1;
- Fe_vi = emission factor for each vehicle type (Emission Factor INEMAR, 2019) as shown in Tab.2;
- Car stock of each individual municipality i (Car stock ISTAT, 2022) as shown in Tab.3.

Municipality	CO_2 eq. (kt/year) from Road transport
Pavia	116.80215
Vigevano	74.07006
Voghera	84.21267
Belgioioso	10.95914
Mede	4.86254
Casteggio	21.57603

Tab.1 Road transport emissions

Vehicle type	Fe CO_2 eq. (g/km)
Car	Fec= 175 g/km
Bus	Feb= 780 g/km
Truck	Fet= 578 g/km
Motorcycles	Fem= 118 g/km

Tab.2 Emission factors

Municipality	Car (Nc)	Bus (Nb)	Truck (Nt)	Motorcycles (Nm)	Vehicle tot.(Nvtot)
Pavia	41,667	275	3,720	8,416	54,078
Vigevano	39,339	100	4,580	6,190	50,209
Voghera	25,565	44	3,106	3,810	32,525
Belgioso	3,759	11	449	503	4,722
Mede	4,354	2	475	526	5,357
Casteggio	4,745	3	892	829	6,469

Tab.3 Car Stock

Dividing the total emissions of CO_2eq. for the number of annual vehicles and their emission factors using the equation (5), the result is an average journey length that each vehicle completes daily in a municipality *i* as shown in Tab.4.

$$L\ vi = (CO2eq\ tot)/(\sum\_i\text{^}n\ 〚Fe\_vi\ xNix365〛) \tag{5}$$

Municipality	L vi	L tot. road lenght (GIS)	% Average journey lenght
Pavia	31.19689616	343.33	9.09%
Vigevano	20.18890757	434.55	4.65%
Voghera	35.0875296	306.23	11.46%
Belgioso	31.21621762	39.41	79.20%
Mede	12.38543464	58.09	21.32%
Casteggio	41.99894233	101.44	41.40%

Tab.4 Average journey length

The average distance of a vehicle in Lombardy is about 30.68 km, so we can consider reasonable the results obtained.

We apply the multiple regression method considering three independent variables (X_1, X_2, X_3) and the dependent variable (Y) where:

- Y_i=CO_2eq tot /year [kt] from the road transport sector of the municipality i;
- X_{1i}=Lvi [km] average daily travel of a vehicle in the municipality i;
- X_{2i}=annual car stock of the municipality i;
- X_{3i}=weighted average of emission factors per vehicle type [g/km] in the municipality.

Municipality	Y	X1	X2	X3
Pavia	116.80 $x10^9$	31,2	19,738,470	0.2141
Vigevano	74.07$x10^9$	20,27	18,326,285	0.2281
Voghera	84.21$x10^9$	35,1	11,871,625	0.2141
Belgioioso	10.96 $x10^9$	31,2	1,723,530	0.2281
Mede	4.86$x10^9$	12,4	1,955,305	0.2141
Casteggio	21.58$x10^9$	41,9	2,361,185	0.2281

Tab.5 Regression model data

The resulting estimated multiple regression model (6) is:

$$Y_i=-61.7574843892764 +0.669540303866588X1_i+7,157,022.21435762X2_i+0.018004428945236X3_i \tag{6}$$

The coefficients in a multiple regression model shall be considered as net regression coefficients. They measure the variation of the response variable Y at one of the explanatory variables when the others are constant.

For a common figure corresponding to an increase of 1 km of the Lvi, emissions would increase by 0.669 kt, for a given vehicle fleet and a given weighted average emission factor.

The coefficient of determination R^2=0.91 means that this relationship is valid for 91% of cases.

For the second part of calculation the variables considered are:

- CO_2eq tot (kt/year) = not industrial combustion emissions of each individual municipality i as shown in Tab.6;
- Gross Floor Area of the buildings for residence, education and health of each municipality, from DBT shapefile (CENED, 2022), as shown in Tab.7;
- Weighted average of the energy performance index = 270.8 kWh/year, calculated through the data on CENED (Energy certification buildings) Lombardy considering buildings with destinations E1 (buildings of all types used as residences and similar) E3 (hospital, clinic or nursing home buildings), E7 (school buildings at all levels and comparable) defined and classified according to D.P.R. 412/93 with energy classes A4 to G. as shown in Tab.8.

Municipality	CO_2 eq. (kt/year) from non-industrial combustion
Pavia	178.36811
Vigevano	122.16594
Voghera	91.95923
Belgioioso	8.96458
Mede	9.9736
Casteggio	12.43398

Tab.6 Not industrial combustion emissions

Municipality	GFA residence (sqm)	GFA health(sqm)	GFA education(sqm)	GFA Total.
Pavia	6,104,130.00	674,983.00	197,241.00	6,976,354.00
Vigevano	5,456,578.00	79,879.00	168,734.00	5,705,191.00
Voghera	3,993,296.00	123,873.00	131,293.00	4,248,462.00
Belgioioso	638,167.00	7,337.00	7,174.00	652,678.00
Mede	788,103.00	14,206.00	10,518.00	812,827.00
Casteggio	1,099,185.00	13,138.00	1,493.00	1,113,816.00

Tab.7 Gross Floor Area

Municipality	KW/smq year	E1 (n)	E3 (n)	E7 (n)
A4	40	1,258	2	4
A3	50	1,234	2	2
A2	70	1,464	7	6
A1	90	1,791	17	8
B	110	2,065	16	10
C	135	3,374	39	30
D	175	6,968	26	92
E	230	10,650	7	65
F	305	17,427	3	28
G	350	31,763	5	4

Tab.8 Energy performance index

We apply the multiple regression method considering one independent variables (X) and the dependent variable (Y) where:

- Y_i= $CO2eq\ tot$ /year [kt] from the non-industrial combustion sector of the municipality i;
- X_{1i}= GFAi x Weighted average of the energy performance index (270.8 KWh/mq anno) x fuel emission factor (0.1998 kg CO_2eq /kWh) of the municipality i [kg].

Municipality	X	Y
Pavia	178.36811	377,461,493.3
Vigevano	122.16594	308,,684,151.4
Voghera	91.95923	229,866,605.2
Belgioioso	8.96458	35,313,691.44
Mede	9.9736	43,978,687.61
Casteggio	12.43398	60,263,950.29

Tab.9 Regression model data

The resulting estimated multiple regression model (7) is:

$$Y_i = Y_i = -12.9977226904399 + 0.47543265875447 X1_i \quad (7)$$

The coefficients in a multiple regression model shall be considered as net regression coefficients. They measure the variation of the response variable Y at one of the explanatory variables when the others are constant. The coefficient of determination R^2=0.98 means that this relationship is valid for 98% of cases.

For a common data in correspondence of a decrease of 1 kg of CO_2eq produced by a building effect of a better energy performance and/or use of a renewable source, the emissions would decrease of 0.475 kt.

3. Conclusion and Discussion

In the paper authors developed a methodology that permits to calculate pollution emissions starting from what is freely available from the Lombardy Region portal.

The main reasons of this attempt lay on the extremely complicated methodology that INEMAR utilizes to calculate the comprehensive emissions of all human actions.

Surely the estimation developed by INEMAR is complete and precise even if it does not give any evidence of the geographical distribution of human activities that generate the emissions.

The recognition of certain parameters "BETA" in the linear formula allows to integrate classical urban planning analysis with the environmental ones. As it has been shown in the text, presented data are evaluated as average values in a specific territory.

According to the proposed estimation it is possible to measure the average pollution of a planned transformation basing on the basic data that usually compose the city plan (Zucaro & Morosini, 2018). Compared to the global emissions of a selected city, this estimation can furnish the impact of various urban modifications with the "zero scenario". Moreover, it is the basis to define mitigation and compensation actions to reduce greenhouse gas emissions (measured as equivalent CO_2).

Starting from previous studies, that demonstrated the lack of correlation among territorial data and emissions, with the new results it seems that this connection has been defined.

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A smart and active mobility assessment protocol for urban regeneration. Application to regeneration projects of medium-sized cities in Emilia-Romagna

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Abstract

Active mobility, within the context of sustainable urban development, plays a crucial role by positively affecting carbon and greenhouse gasses emissions, promoting healthy lifestyles, relieving urban traffic congestion, and therefore enanching the overall quality of urban life. Nowadays, active mobility plays a crucial role also in the contexts of urban regeneration projects, as highlighted both within the framework of Smart City assessments and within the main urban regeneration evaluation protocols.

This paper pursues to establish a protocol for assessing the transformation of public spaces in the context of urban regeneration, using specific indicators to measure impacts on active mobility. The proposed assessment method aims at benchmarking urban regeneration initiatives, with a particular focus on mobility and accessibility issues.

The methodology has been tested in several case studies within the major medium-sized cities of the Emilia-Romagna Region (Parma, Reggio Emilia, Modena, Cesena and Rimini), in the North of Italy, outlining potential guidelines for the integration of active and smart mobility in the processes of urban regeneration.

Keywords

Active mobility; Urban regeneration; Assessment protocols

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1. Introduction

The transport sector is recognised as a main responsible for energy consumption and pollution in cities. At European level, transport emissions represent around 25% of the total greenhouse gasses (GHGs) emissions, of which CO_2 represents 98.9% (European Environmental Agency, 2023).

At the global level, transport decarbonization issues are central both within the main European directives on urban development, environmental sustainability, renewable energy, smart and sustainable mobility (see, i.a., Agenda 2030; European Green Deal; New European Bauhaus) and in the research (Banister, 2008; Conticelli et al., 2018; Garau et al., 2016; Kenworthy, 2006; Litman & Burwell, 2006; Niglio & Comitale, 2015; Pinna et al., 2017).

Urban Mobility also represents one of the six axes on which the framework of Smart Cities, a research field that has been steadily growing in the last decade, roots (Giffinger et al., 2007). Smart Mobility also plays a crucial role within several Smart City initiatives (e.g. 'Smart cities and communities', 2011; 'Smart cities and communities and social innovation', 2012). It is usually implemented both through Information and Communication Technologies (Behrendt, 2019), and through complex sets of projects and actions aimed at improving the efficiency, effectiveness and environmental sustainability of nowadays cities with the goal of increasing the life quality of citizens (Benevolo et al., 2016; Gaglione et al., 2019; Gaglione, 2023). Smart mobility intertwines to sustainable mobility and aims at reducing traffic congestion within urban areas and improving road safety. These objectives also closely relate to active mobility, which allows addressing several issues: the physical network, the role of urban functions according to their multimodal accessibility, the mixed use of the same spaces by different users and the positive and healthy behaviours related to bicycle and pedestrian mobility (D'Amico, 2023; De Lotto et al., 2022; Garau et al., 2016). For this reason, some authors (see, i.a., Francini et al., 2021; Ketter et al., 2023; Garau et al., 2023; Torres et al., 2021) use the term 'smart sustainable mobility' in their studies.

Some measures to achieve sustainable mobility are the promotion of the local public transport instead of private vehicles and the integration of urban and transport planning. Participation and communication are important as well as sensibilisation actions that can act directly on the behaviour and habits of people (Spadaro et al., 2023).

Highlighting active mobility rather than motorised traffic, as emerged from studies on the 15-minute city in recent years, has positive implications in spatial as well as environmental, functional and social terms too (Pinto & Akhavan, 2021; Venco, 2021). And medium-distance bicycle and pedestrian routes are seen as essential elements for the sustainable development and renewal of the urban texture (De Lotto et al., 2022).

At the operational level, Sustainable Urban Mobility Plans (SUMPs) represent the main planning tool to solve transport inefficiencies in cities with an integrated and sustainable approach. These plans show to be especially significant since they prioritise the well-being of citizens and an effective performance of activities rather than traffic flows. The criteria with which these new plans address the problems of urban space have deep similarities with quality criteria expected from urban regeneration processes (Bollini et al., 2018; Bollini et al., 2018; Niglio & Comitale, 2015).

In this context, the enhancement of accessibility to public services and facilities and the re-design of the road system became essential to achieve sustainability within urban regeneration processes (see, i.a., Carra et al., 2022; Ignaccolo et al., 2020; Spadaro et al., 2023; Tiboni et al., 2021; Tira, 2018).

Within this framework, this paper aims at defining a protocol to assess smart and active mobility indicators in urban regeneration projects, and at applying it to urban regeneration interventions recently developed in medium-sized cities of the Emilia-Romagna Region, in Italy. Based on the outlined framework, the protocol roots on indicators derived from the Smart Cities rankings and/or adopted to evaluate urban regeneration processes.

The paper is structured as follows: section 2 frames review the mobility issue within existing Smart City rankings and urban regeneration evaluation protocols. Section 3 illustrates the proposed protocol to assess smart and active mobility within urban regeneration projects. It also presents the summary of the five urban regeneration study cases in the Emilia-Romagna Region in Italy. Section 4 presents the results of the assessment and outlines a comparison among the studied cases. Section 5 provides a discussion of the results and discusses the results. Finally, section 6 illustrates some conclusive remarks and outlines possible guidelines for the implementation of urban regeneration projects.

2. A review of assessment methodologies for smart and active mobility

Smart City rankings (e.g. ICity Rank, European Smart City Ranking of the medium-sized cities, Smart City Index) and existing urban regeneration protocols (e.g. the GBC Quartieri protocol of Green Building Council Italia, the ITACA protocol and the AUDIS Urban Quality Matrix) already proposes several indicators to assess smart and active mobility.

This section provides a review of existing indicators and protocols, in order to frame a methodological approach to assess the impacts of urban regeneration projects on active mobility and accessibility.

In particular, the review considers the analysis of five Smart City rankings and of three existing protocols for evaluating urban regeneration interventions.

2.1 Mobility indicators within Smart City rankings

Data from Smart City rankings, which were analysed among those at European, Italian and regional level, can be summarised as follows:

- The 'European Smart City Ranking of the medium-sized cities', developed at European level, considers four factors in the field of mobility: local accessibility; international accessibility; availability of ICT infrastructure; and sustainable, innovative and safe transport systems (Ranking of European medium-sized cities, 2007);
- The 'Smart City Index' is instead developed in Italy, and it is annually updated by Ernst & Young. It includes indicators related to mobility for different purposes: traffic reduction; decrease of polluting vehicles; electric and hybrid mobility promotion; and the development of alternative mobility options. Regarding active mobility issues, it includes specific data as the kilometers of cycle lanes or the number of shared bicycles (Smart City Index, 2020);
- The third ranking considered is the 'ICity Rank', which, like the previous one, is national. It consists of 16 indicators related to mobility areas, including public transport development, impact of vehicle traffic, mobility governance tools, dissemination of participatory processes, and pays attention to the density of cycle lanes and the square meters of pedestrianised areas (Icity Rank, 2021);
- The fourth classification is the 'International Standard ISO 37122- Sustainable cities and Communities' developed by the International Organization for Standardization, in particular by the committee "ISO/TC 268, Sustainable cities and communities", drawn up in 2019. It adopts 14 indicators, including the use of traffic sensors, low-emission vehicles, the availability of sharing services, public transport, and innovative vehicles (ISO 37122, 2019);
- Finally, the SmartER measurement, developed in 2018 by the Emilia-Romagna Region, analyses the technological, environmental, and human dimensions. It includes indicators on the density of cycle lanes, bike sharing availability and some qualitative indicators (SmartER, 2018).

In Italy, several Smart projects developed in the national context also serve as examples of the focus placed on active mobility (Caselli et al., 2022; Pinna et al., 2017). According to the Italian Smart Cities platform, the particular interest of administrations emerges in the theme of cycle mobility, shared mobility, pedestrian mobility and improving local public transport. There are some recurring measures that can be highlighted, not only from the indexes listed above, but also within the literature, and that refers to sharing mobility, traffic calming and slow mobility. They aim at enhancing road safety (as in Batomen et al., 2023), at giving to active transportation modes a more central role in urban transportation (as in Tight et al., 2011), at improving environmental sustainability (also with e-mobility solutions, as in D'Acierno et al., 2022) and at reducing private cars use (with particular reference to the sharing systems, as in Tesoriere et al., 2020).

2.2 Mobility indicators within Urban Regeneration protocols

In the literature, there are many protocols to assess urban regeneration interventions, which consider all the aspects of a regeneration project (social, economic, environmental, etc.) often adopting holistic and comprehensive approaches. They also include measures for 'mobility' both to incentive the environmental sustainability, and 'traditional' needs like car parkings. With reference to active mobility issues, the three Italian protocols anlysed (the GBC Quartieri protocol of Green Building Council Italia of 2015, the ITACA protocol of 2016, the Urban Quality Matrix of AUDIS - Associazione Aree Urbane Dismesse - of 2017), highlight the following characteristics:

- The Green Building Council (GBC) protocol stresses accessibility to the public transport system within a 400-metre radius of the buildings, proximity (400 metres) to the bicycle network, and pedestrian accessibility of the streets network, which mainly involves the continuity of footpaths (GBC Quartieri, 2015);
- The Itaca protocol pays attention in particular to public transport, to the improvement of cycle and pedestrian accessibility, and also the development of innovative systems such as the bike sharing (ITACA protocol, 2016);
- The Urban Quality Matrix considers mobility from a wider perspective. It includes the urban quality (the urban equipment of infrastructure for public and private mobility), and the quality of public spaces (accessibility, usability and safety) (AUDIS urban quality Matrix).

Furthermore, the cities of the Emilia-Romagna Region have set up some indicators in the occasion of the Regional Call for Urban Regeneration in 2018 for their projects (Pellicelli et al., 2022). These include: the presence of pedestrian and bicycle accesses, the increase or decrease in the length of bicycle lanes, bike sharing stations, street furniture (seats, water elements, bicycle racks), green spaces and trees.

3. Defining a protocol of smart and active mobility indicators for urban regeneration contexts

As highlighted in the previous section, in the literature, indicators belonging to Smart City rankings were originally designed for an application at the municipal scale, with the aim of comparing different cities, while indicators developed within urban regeneration evaluation protocols are already applicable at the neighbourhood scale. How can those indicators be merged, elaborated and integrated to evaluate urban regeneration contexts?

The proposed protocol aims at defining an assessment method that integrates the inidcators implemented so far through the urban regeneration protocols with the Smart City mobility assessment, by creating a schedule of analysis to assess with a single set of indicators the accessibility of services, in particular to the sites under intervention, within urban regeneration processes.

To integrate existing indicators and derive a comprehensive assessment protocol, an evaluation sheet has been developed. Indicators have been divided into 'qualitative', i.e. those indicators which require the verification of the existence of certain elements, and 'quantitative', i.e. those that relate different variables and measures the increase or decrease of certain factors (Tab.1).

Topic	Indicator	SC ranking	UR protocol
Public transport	Pedestrian accessibility to public transport within 400 m		GBC / ITACA
Ciclability	Density of bicycle lanes: km bicycle lanes per 100 km^2 of municipal area	ICity Rank / SmartER	
	Km of cycle paths and lanes per 100,000 inhabitants	EY Smart City	
	A maximum distance of 400 m from an existing cycle network connecting the area to a workplace, school service, basic service or rapid transport stop located within 4 km.		GBC
	Availability of safe cycling routes		ITACA
	Contiguity of bicycle and vehicular routes		ITACA
Walkability	m^2 pedestrianised road surface per 100 inhabitants	ICity rank	
	Pedestrian accessibility of streets		GBC
	Accessibility of footpaths		ITACA
Innovative services	% of non-motorised travel out of total transport	EY Smart City	
	Bike Sharing Diffusion (n. bikes/100 in.)	ICity Rank / ISO 37122 / SmartER	
	Number of shared bicycles per inhabitant	EY Smart City	
	Number of sharing economy transport users per 100,000 inhabitants	ISO 37122	
	Municipalities with car sharing service	SmartER	
	Municipalities with LTZ (Limited Traffic Zone)	SmartER	
	Municipalities participating in the regional platform "Mi muovo"	SmartER	
	Accessibility to shared mobility (in %) of the population within 400m of the sharing station or within 300m of the sharing station		GBC / ITACA
Safety	% LTZ on total area	ICity rank	
	% of residential roads with a speed limit of 30 km/h		GBC
	Reduction of parking areas (max. 8,000 m^2)		GBC
	Security of public space		AUDIS

Tab.1 Qualitative and quantitative indicators divided in main clusters and referred both to the Smart City ranking and urban regeneration protocols assessment

3.1 Case studies selection

The protocol was applied to some medium-sized cities that are similar in conditions, location, and population size to test the methodology and verify the possibility of identifying the project that most improves the existing conditions concerning smart and active mobility in the regeneration areas.

Selected Urban Regeneration projects were evaluated from the perspective of sustainable mobility by checking smart and sustainable active mobility indicators taken from Smart City rankings and urban regeneration process evaluation protocols, as seen before, and partially adapted to the context of the medium-sized city.

The cities have been selected on the basis of the following considerations:

- the location must include municipalities throughout the Emilia-Romagna region;
- urban regeneration strategies must include not only the redesign of public space but also of mobility-related services;
- the size of the urban regeneration project areas must be of comparable size in all cities.

Five provincial capitals of the Emilia-Romagna Region, in the North of Italy, have been selected, referring to urban regeneration projects that the cities presented in the 2018 Regional Call for Proposals on Urban Regeneration and mostly focused on accessibility issues (Pellicelli et al., 2022). Selected projects are located in the cities of Parma, Reggio Emilia, Modena, Cesena and Rimini.

Selected urban regeneration interventions are located in different parts of the cities. The urban regeneration sites are comparable in size, occupying approximately a urban block. Moreover, calls for proposals that finance urban regeneration interventions are suitable for evaluation according to pre-established criteria due to their characteristic of competitiveness, and therefore of evaluation of their performance by the administration. Finally, the public call is an opportunity to implement urban regeneration projects, which, despite being promoted by the recent Regional Law No. 24 of 2017, are often realized by private operators. Public funding is instead an opportunity to redesign the urban space by improving mobility and accessibility, and more general the quality of the context and therefore the quality of life.

The selected urban regeneration project in Parma is located in the north-west sector of the city, outside the historic centre, and concerned the construction of a new library. The project involved the creation of a new urban centrality with a variety of services for citizens: greenery, car parking and meeting areas. It aimed not only at enhancing slow mobility, but also at a general reorganisation of the mobility system in the surrounding neighbourhood to make the area more easily accessible. Adopted solutions included the introduction of a 30 km/h zone and the extension of the bicycle network.

In Reggio Emilia the area interested by the urban regeneration project is located in the eastern part of the city, in the immediate proximity of the historical centre. The area is strategic since it connects the centre, neighbourhoods and polarities such as industrial areas and the train station. The project envisaged the construction of a new building to host the Municipal Police office as well as the reconnection between the different areas from a traffic point of view and the enhancement of the slow mobility network.

The project proposed by the Municipality of Modena was in the Modena East district, within a former industrial area. The regeneration aimed at re-functioning the area and creating a new district for the development of start-ups operating in the field of automotive technologies and sustainable mobility. The area is rich in cycle paths and bike sharing stations, while Zone 30 had to be enhanced.

The Urban Regeneration project of Cesena was located in the historic centre, and involved the redevelopment of three squares: Piazza Bufalini, Piazza Almerici and Piazza Fabbri. The area was before a road for vehicular traffic and was occupied by car parkings. The project involved expanding the green areas, and pedestrianizing nearly the entire square.

The project financed in the Municipality of Rimini was located in the Miramare coastal area, in the Esatern part of the municipal territory. The project included the redesign of the road section of the seafront, before exclusively dedicated to vehicular traffic, making it pedestrian and bicycle friendly. The redesign provided a pedestrian area, towards the beach, a cycle lane on the built-up area side, and in the central area an equipped band, with draining paving and green areas, which was lacking, street furniture and a bike sharing station.

4. Results

The following tables (Tab.2 and Tab.3) presents the results obtained, also to allow a more easily comparison among the cities' interventions.

Domain	Indicator	Factors	Projects evaluation: Parma	Reggio Emilia	Modena	Cesena	Rimini
Municipality	Municipalities participating in the regional platform "mi muovo"		+	+	+	+	+
	Drafting the SUMP		+	+	+	+	+
	Existing LTZ		+	+	+	+	+
	Car sharing service		+	+	+	+	+
Project Area of Influence	The project contributes to the realisation of the SUMP	Cycle lanes	+	—	—	—	+
		Pedestrian connections	+	—	—	+	+
		Other elements	+	—	—	—	—
	Zone 30		+	—	—	—	—
Project area	Green	Grassland	—	—	—	+	+
		New trees	+	—	—	—	+
	Street furniture	Seating	+	—	—	+	+
		Bicycle racks	+	—	—	+	+
		Water surfaces	—	—	—	+	—
		Play areas	+	—	—	—	+
	Bicycle and pedestrian accessibility		+	—	+	+	+
	400 m distance from a cycle network		+	+	+	+	+
	Bike sharing station		—	—	—	0	+

Tab.2 Qualitative indicators assessed. The symbol '+' indicates that the requirement is satisfied, on the contrary '-' indicates that it is not considered in the regeneration project, finally, "0" means that the element is already present in the area

Theme	Indicator	Projects evaluation: Parma	Reggio Emilia	Modena	Cesena	Rimini
Sharing	Bike Sharing Diffusion (n. bikes/100 in.)	No stations	0.73 bikes/ 100 inh	No stations	0.35 bikes/ 100 inh	0.30 bikes/ 100 inh
	Potential service users (%) [(pop. within 5' from station)/(tot. in.)]*100	3.1 %	76 %	7 %	45 %	30 %
Cyclability	Availability of safe cycling routes (m cycle lanes/100 in.)	44 m/100inh	88m/ 100inh	105.7 m/ 100 inh	43.5 m/ 100inh	19 m/ 100inh
	Conjunction of cycle and vehicular routes (%) [(m cycle lanes / streets tot m)]*100	25 %	44 %	48 %	13.5 %	5.6 %
Walkability	Availability of pedestrianised area (m^2 pedestrian area / 100 in.)	1.6 m^2/inh	3.81 m^2/inh	2.4 m^2/inh	5.3 m^2/inh	3.2 m^2/inh
	Extension of pedestrian areas [(m^2 pedestrian area / m^2 area)]*100	1.5%	2.7%	1.4%	4.2%	1.3%
	Pedestrian accessibility of streets [(m street with sidewalks / streets tot m)]*100	75.4%	54.2%	43.6%	66%	40%
Safety	Zone 30 Extension [(m^2 area Zone30 / m^2 area)]*100	47 %	30 %	/	/	/

Tab.3 Quantitative indicators assessed within the urban regeneration framework

As mentioned above, unlike the indicators in Tab.1, those in Tab.2 involves the measurement of different factors and are the ones that will lead to an effective assessment, as explained in the following chapter.
Looking at the results, all municipalities has joined the regional mobility platform and have all approved a Sustainable Mobility Plan (SUMP) between 2017 and 2020.
Except for the Parma project, the analysed urban regeneration interventions do not, however, take into account possibilities of employing the redesign of urban space to address demands as outlined within the SUMP. In three examples (Parma, Cesena, and Rimini), 'urban furniture' is an essential component of the redevelopment effort; in the other two, it is not. The same happens with reference to urban green areas. Water mirrors and fountains are an exception because they are limited to the Municipality of Cesena's proposal. However, except for the Municipality of Reggio Emilia, where the area is zoned for a private development, each project's specific study highlights a positive impact on pedestrian and bicycle accessibility.
Lastly, bike sharing is an even more complicated factor to consider. Since urban regeneration projects are located in the immediate proximity of the historic centre, they do not provide new bike sharing stations (with the exception of Rimini), despite the fact that the accessibility to existing bike sharing stations is in 3 cases still limited, i.e. reachable on foot in 15 minutes or more (Fig.1).

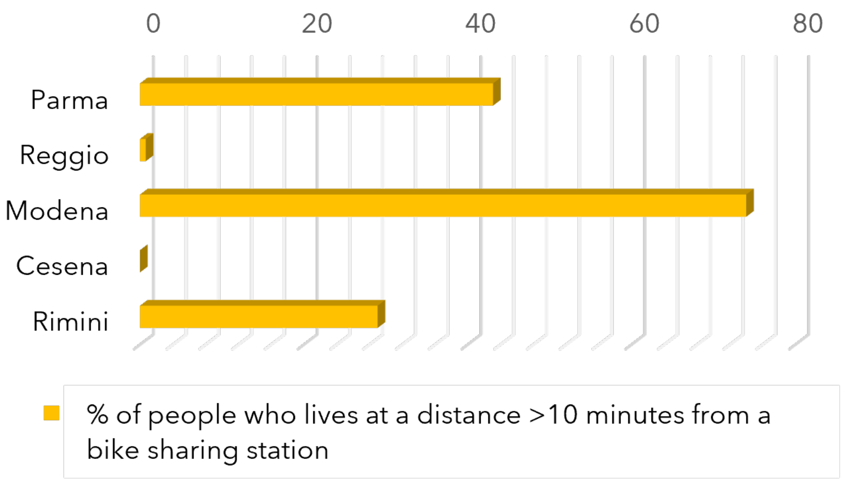


Fig.1 Percentage of residents living beyond a pedestrian distance of 10 minutes from the stations as a result of the regeneration project

5. Discussion

The conducted investigations allowed a comparison of mobility performance and its improvement or decrease in the urban regeneration contexts of the analysed cities.
However, to what extent does an urban regeneration process actually succeed in influencing and improving the urban environment with regard to concerns like user safety, reconnecting long-distance routes and cycle lanes, and urban liveability? Do people who live in urban regeneration choose to walk or cycle instead to drive a private vehicle?
Urban areas chosen for regeneration interventions may, depending on the municipality, either still be largely devoid of adequate infrastructures for cycle and pedestrian accessibility, or they may already be effectively supplied. The pre-existing situation, i.e. the infrastructure already in place and accessible in the regeneration area, is in fact tied to the factors. How can we figure out which project performed best?
The variables are in fact closely intertwined to the pre-existing situation.
The most enhanced categories were defined using an algorithm derived by the multi-criteria analysis. Six of the criteria, related to slow mobility (pedestrian areas, pedestrian paths, cycle paths, bike sharing stations, 30 km/h zones, green areas) were considered as values, that means that their increase corresponds to an increase

in the overall rating. The other two criteria (parkings and vehicular roads) were considered as costs, so their decrease are considered a cost saving that led to a better overall rating. This explains why all values showed in Fig.2 are displayed as positive, e.g. the vehicular roads rate is high in Rimini case, thanks to the great reduction of road surface planned in its intervention.

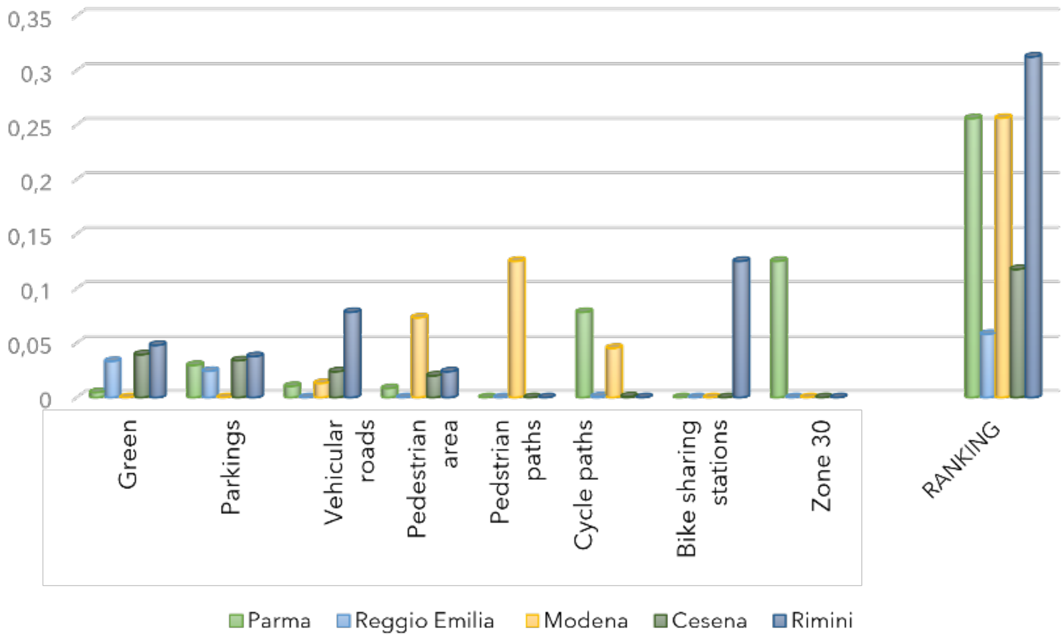
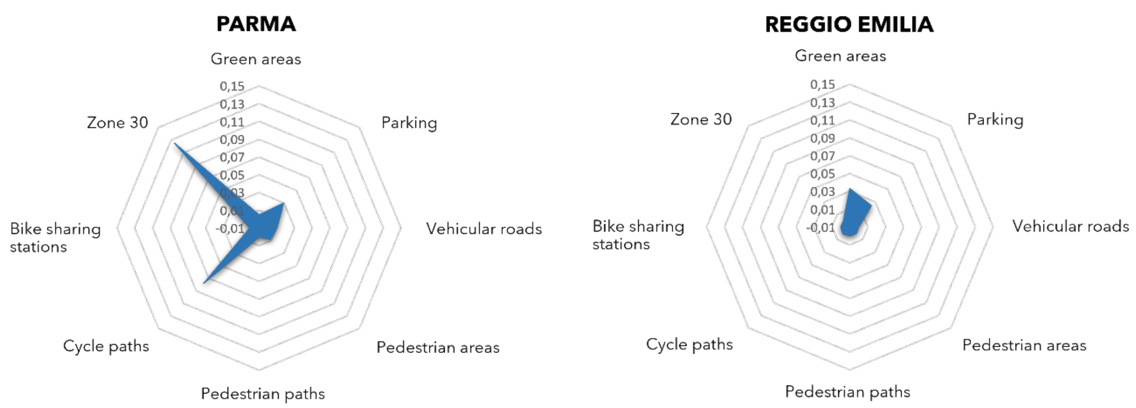


Fig.2 Increase or decrease of accessibility factors as a result of regeneration projects, normalised

Furthermore, Fig.3 represents the graph reorganised by city, showing in which areas each case study achieved the best results, represented by the outward peaks.
We can have a clear idea of the major impacts generated by the urban regeneration intervention. The city of Parma developed the expansion of the Zone 30 and connected two cycle lanes to each other. The city of Reggio Emilia proved a contrary action, in public space it privileged vehicular mobility. The city of Modena increased the pedestrian paths, connecting the two sides of the former industrial compartment with walkways. The city of Cesena enhanced the pedestrian areas, transforming the vehicular roads into pedestrian ones, and completely pedestrianised the squares, but it did not impact very much because it was already rich in pedestrian paths, but we can see the increasing of the green areas. Finally, the city of Rimini as well intensify different sphere, the most conspicuous is the bike sharing service, but also the reduction of vehicular traffic and the boost of green areas are remarkable.



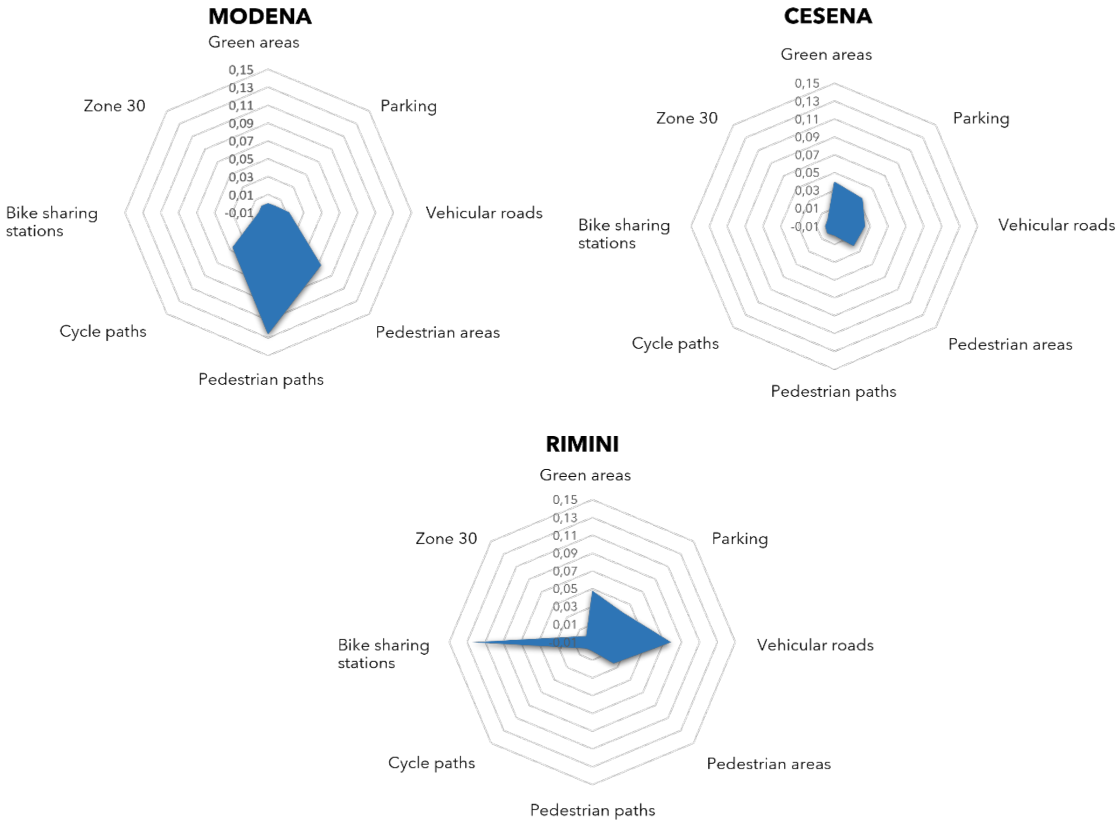


Fig.3 Overview of the enhancement of the criteria for the city of Parma, Reggio Emilia, Modena, Cesena and Rimini

6. Conclusive remarks

The paper proposed a protocol to evaluate smart and active mobility within urban regeneration interventions, deriving specific indicators for mobility re-elaborated from urban regeneration assessment protocols and Smart City rankings. The paper applied the protocol to five medium-sized cities in the North of Italy, to compare their projects form the smart and active mobility perspective.

Indeed, this assessment protocol enables measuring the rise in active and smart mobility characteristics within urban regeneration projects, and, as a result, comparing different projects. Therefore, it can be applied as an evaluation tool for urban regeneration processes to qualifying and promoting active smart mobility.

The proposed methodology could be used to compare different project proposals, for example during the evaluation phases of public calls for urban regeneration to assess the improvement of active mobility and accessibility to the regeneration area.

The evaluation process measures the progress in accessibility rather than the optimal location of urban regeneration interventions. The evaluation process is therefore not appropriate to use it as a tool to identify the priority areas for urban regeneration initiatives. On the other hand, where there is a lack of accessibility via environmentally friendly modal choices, it may be able to improve regeneration performance using the indicated indications.

The Regional Urban Regeneration Call placed a strong emphasis on redesigning transport infrastructures to support active modes and, more broadly, sustainable mobility. This is a crucial component of the Sustainable Development Goals (SDGs) established by the United Nations 2030 Agenda (UN-GA, 2015), but it is also favored by UN-Habitat's New Urban Agenda (UN-HABITAT, 2017), which prioritizes non-motorised transportation modes like walking and cycling over motorised private transportation.

As seen, there are numerous methods that operate on various scales to evaluate active mobility in urban areas. Evaluation processes certainly contributes to focus attention to the topic.

The study shows how much urban regeneration and mobility issues are intertwined: urban mobility, safety and environmental sustainability represent pillars of all the analysed regeneration strategies. As the literature highlight, is important to achieve sustainability regarding the field of mobility, because clean and soft mobility combined with increased accessibility and the advent of new technologies can reduce environmental and social costs (D'Amico, 2023).

Because the methodology is implemented retroactively, and the administrations already received fundings for the interventions, this choice of analyse competitive calls is a pretext to test the effectiveness of the indicators, which may be used for future calls.

From the results of the analysed cities, some possible guidelines for regeneration processes clearly emerge. In particular, it is possible to stress the necessity of:

- Integration of SUMPs with urban regeneration interventions;
- Expansion of 30 kmph zones in contexts that are close to the historic centre or smaller urban centers;
- Checking the accessibility of bike sharing services. Although it is not possible for all people to be served by shared bicycle, it would be convenient for each location to be close enough to give numerous people the opportunity to reach it by walking. This could become an attractive alternative to private car use;
- Integration of traffic components that considers each user's demands and ensures their safety with appropriate traffic calming techniques;
- Integration of elements derived from SEAPs (Sustainable Energy Action Plans), that promote environmental sustainability in open spaces, especially near streets or pedestrian spaces, such as fountains, seating and street furniture elements. These would benefit the environment and act as attractive elements also for pedestrians.

The main limitations of this work are related to the indicators used. Although the most frequently used indexes in the literature for evaluating Smart Cities have been considered, there are numerous indexes that assess urban characteristics and quality of life.

Future developments to this work could include the improvement of the evaluation methodology, i.e. the recalibration of the indicators to take into account the use of the area after the project implementation, as well as the enrichment of the data for a more accurate evaluation and, finally, the improvement of the analysis' level of detail (i.e. including further criteria, like the presence and location of architectural barriers etc.).

Furthermore, despite the fact that each municipality has different needs, the protocol application may set maximum levels for each indicator to work towards, so that each example can be compared with an 'ideal' rather than just with other comparable cases.

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Image Sources

Figg.1, 2, 3: elaborated by the authors.

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Assessment of urban green spaces proximity to develop the green infrastructure strategy. An Italian case study

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Abstract

To consolidate new models of sustainable growth based on the management of natural resources, the traditional spatial planning tools are being integrated with new approaches based on ecological and environmental "performance" which consider the provision of ecosystem services through the design of Green Infrastructure (GI), a possible way to improve the quality of life in the contemporary city. The paper describes a sectoral study developed on the public green spaces system at the city scale. The work is part of a research project aimed at developing strategic guidelines for Green Infrastructures at the local scale for the definition of the new Urban Green Plan of the Municipality of Falconara Marittima, located in the province of Ancona (center of Italy), selected as a case study. The study provides a method to estimate the proximity of urban green spaces based on the evaluation of their level of accessibility and usability, to maximize the provision of cultural ecosystem services in response to citizen needs. This contribution aims to help public administrations in evaluating the 'performance' of green spaces based on the ecosystem services approach to support urban and territorial planning and decision-making tools.

Keywords

Green infrastructure; Ecosystem services; Urban green spaces proximity.

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1. Introduction

To consolidate new models of sustainable growth based on the management of natural resources, the traditional spatial planning tools are being integrated with new approaches based on ecological and environmental "performance" (Auzins et al., 2014; Kendig, 1980) which consider the provision of ecosystem services through the design of Green Infrastructure (GI), a possible way to improve the quality of life in the contemporary city (Gómez-Baggethun et al., 2010; Ronchi et al., 2020).
Defined as "network of natural and seminatural areas with other environmental features that is supposed to deliver ecosystem services (ES)" (EU, 2013), GI is considered the most adequate tool aim at planning, design, and manage a framework of Urban Green Spaces (UGS) (Chatzimentor et al., 2020) at the city scale, which represent key elements for the conservation of biodiversity and landscapes (Casavecchia et al., 2020) and the provisioning of regulating ES (Gómez-Baggethun & Barton, 2013a; Gómez-Baggethun & Barton, 2013b), particularly relevant for their beneficial effects on physical and mental health (Tamosiunas et al., 2014).
In fact, some of the most significatively ecosystem functions (such as shading, evapotranspiration and wind shielding (Cortinovis & Geneletti, 2020)) performed by UGS can significatively contribute to improve cooling capacity of the urban ecosystems to contrast urban heat islands (Singh et al., 2020). Several studies also demonstrate that UGS plays a fundamental role in provision of cultural ecosystem services (CES) (Andersson et al., 2015; Carrus et al., 2013; Haines-Young & Potschin, 2018) such as recreational activities, sense of place, health, and aesthetical values (de Groot et al., 2012; Gómez-Baggethun & Barton, 2013b).
Since the social benefit deriving from ES depends on the proximity of UGS inside the cities, measured by their level of accessibility and usability (De Luca et al., 2021) it is essential to investigate a complete set of indices; not just the 'quantity' of UGS through the development of specific indicators and parameters (De La Barrera et al., 2016), but also the availability and the spatial distribution of UGS according to social milieu and specific demand, to be effective in propose planning policies.
Moreover, benefit deriving to ecosystem services provided by urban environment can improve public value. This aspect is supported by several studies that aim to quantify through monetization the benefits in terms of health linked to the presence of green areas in cities (EEA, 2022; Lee et al., 2015).
In this context, the research work evaluates the proximity (Maas et al., 2006) of UGS with high ecosystem values within the urban areas. The methodology was based on the assessment of the level of accessibility ad usability of UGS within the site-specific network systems and urban settlement barriers.
Specifically, analysis have been conducted in the municipality of Falconara Marittima (province of Ancona), located in Marche region (central part of Italy), where the Department of Materials, Environmental Sciences and Urban Planning of Marche Polytechnic University provide the scientific support to draw up the Green Masterplan. In this scenario, this sectoral instrument allows us to define a new vision for the future development of the green component of the city, supported by the Green and Blue Infrastructure concepts and applications (EU, 2013).
Here, to perform a geostatistical analysis of the distribution of public green areas and population served by them have been essential to support planning action aimed at guaranteeing an equal distribution of green spaces based on citizen's needs and supporting in the definition of the hierarchy of priority interventions for development GI policies and strategies.
The analytic process is multi-object, as it considers elements from different information databases, including the regional ecological networks (REM, *Rete Ecologica Marche*), the Regional Landscape Plan (PPAR*, Piano Paesistico Ambientale Regionale*) and the Provincial Territorial Plan (PTC, *Piano Territoriale di Coordinamento Porvinciale*), which constitute the main reference framework of the project; but also, multiscale. In fact, data was obtained both from the downscaling of ESA Copernicus program databases but also from municipality databases. Moreover, demographic analysis allows to define the target of residential population that can potentially benefit from the ecosystem services provided by the Urban Green Infrastructure (UGI).

Accessibility to UGS seen as the maximum distance to travel from the residence to a public green area is now considered a key parameter for measuring the quality of green infrastructures on a city scale (WHO, 2017), and for defining planning strategies aimed at overcoming disparities in accessing these resources, with a view to equity and justice (Rishbeth, 2010). To evaluate the proximity of UGS related to the population served would orient planning and management strategies to build the strategic vision of the green system within the land-use plan (Vignoli et al., 2021). Moreover, contributes to defining a qualitative criterion to guide the green infrastructures design and to improve the efficiency of land use and so the quality of the Land use plan (Auziņš & Viesturs, 2017; Botticini et al., 2022).

2. Material and Methods

2.1 General approach and data input

A multi-scale methodology has been developed as a support for the strategic design of green infrastructure. According to the principles of GI such as multifunctionality (GI as a tool for ecological, economic, and social enhancement), multiscale and "multi-object" (i.e. integration) principles (Benedict & MacMahon, 2002; Hansen & Pauleit, 2014; Monteiro et al., 2020), the analysis is based on multiple factors, incorporate elements from different sources and with different detail scales. These elements refer both to ecological and socio-demographic aspects. To bridge these two spheres, a network analysis was carried out to evaluate the proximity of UGS, based on the assessment of the level of accessibility and the usability of green areas (Quatrini et al., 2019) (Fig.1). In this general framework, this contribution describes an experimental study conducted on public green spaces at the urban scale, essential for redesigning the continuity of green infrastructures within the city (Tulisi, 2017).

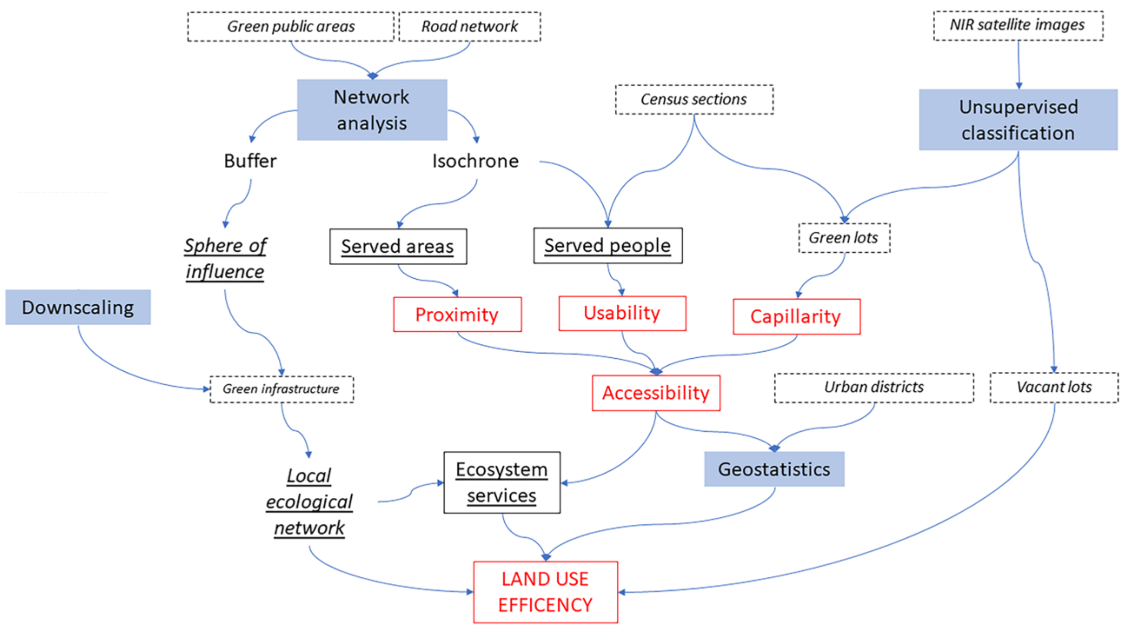

Fig.1 Methodological process for the creation of the cognitive framework at the basis of the project of the local ecological network (municipality of Falconara Marittima). The scheme highlights: a) input data (dotted line); b) goals of the research (red); c) different procedures used to connect the various elements (blue); d) main results (black)

3. Case study

Falconara Marittima is a small town located in the terminal part of the Esino river valley on the Adriatic coast and close to Ancona, the regional capital of the Marche region (central Italy, Fig.2).

The municipal area extends for 25.81 km^2, with a residential population of 25,727 and a population density of 996.78 inhabitants/ km^2 (ISPRA, 2022; ISTAT 2021).

Here, the urban area (a) measure 7.9 km^2 while the natural area (b) about 20 km^2, that corresponds respectively 31% and 77% of the total administrative land area.

We limited the analysis to green spaces within the urban area (a) selected as the study area. Here, UGS represents approximately 1.98 km^2, equal to 25% of the total (a).

Fig.2 Ecological connectivity of urban green spaces of Falconara Marittima. The green systems connect peri-urban and rural areas to the sea

Then, according to urban morphology and development of the city, the study area has been divided in three districts: 1) city center - 2.1 km^2; 2) Castelferretti - 3.1 km^2; 3) Rocca-Villanova - 2.7 km^2.

The study intends to outline new strategies to increase the multifunctionality of greenery and the provision of ES that supported the Municipality for the development of Green Masterplan to improve the quality of the Land Use Plan (the Italian General Urban Plan, PRG). The main goal of the applications was to add qualitative criteria based on the comparison of demand / supply of ES to select areas with priority of intervention. This operation is essential in supporting the decision-making process and helps urban planners to outline future scenarios and direct economic resources based on citizens' needs. To do so, we firstly analyse the framework of the 'green standard' for public facilities (Italian Ministerial Decree n. 1444/68) as a part of the green component of the Land Use Plan (UGS) at the city scale. Here, we outline a critical situation. In fact, just the 16% of green standards of the public green areas have been developed (and currently manage) by the Municipality, while the 84% of the total of green areas are not implemented and therefore unable to maximize the provision of CES to citizens (Fig.3).

These data highlight the need to define new policies and strategies to plan and design UGS to implement GI at the city scale. Strategies could be based on these two main approaches:

a) to better orient financial resources (for example the adoption of diversified maintenance and management criteria of green spaces (Pantaloni et al., 2022));
b) to draw up the revisions of the Land Use Plan by proposing appropriate zoning variations to implement green standard services based on city users and specific targets of resident.

Therefore, to build qualitative evaluation criteria we develop a series of sectorial study including the network analysis to assess the urban green spaces proximity, described as follows.

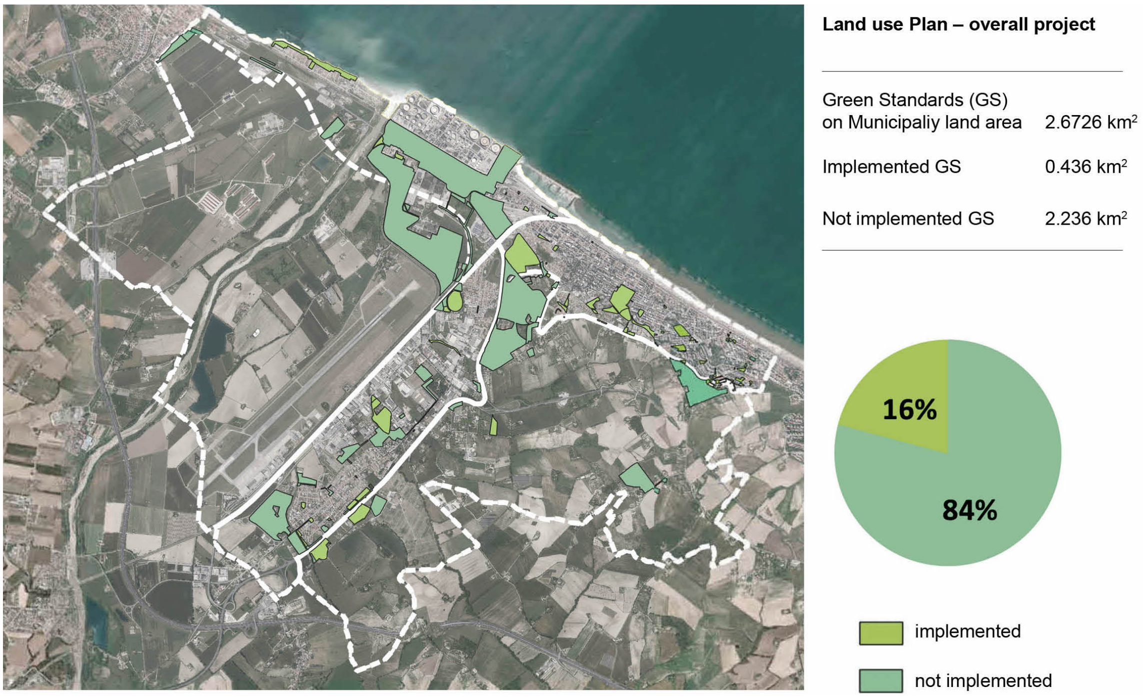

Fig.3 Urban green spaces analysis on the three urban district

3.1 Accessibility and usability assessment: urban area

At the city scale, we first evaluated the accessibility level (Nicholls, 2001) within the three selected urban districts. For this purpose, we perform network analysis testing the isochronous method (Tiboni et al., 2021). It allowed to identify the iso-distances calculated by evaluating the walking area within a radius of 300 m and 800 m, corresponding to about 5 minutes and 15 minutes (Busi, 2009, 2011; Tiboni & Rossetti, 2014).

To do this, we considered the following spatial layers as input data:

a) the public green spaces managed by the Municipality of Falconara Marittima;

b) infrastructure system (streets and roads).

The assessment of (a) has been developed by applying a multi-scale and multilevel overlay process, concerning:

1) downscaling of the environmental elements of the regional planning instruments (Pantaloni et al., 2023);

2) mapping the green census resources developed at the city scale.

Spatial data such as public green spaces, network system and street furniture have been provided by the Municipality Topographic Database of the Green Heritage manageable through the QGIS open-source software (SIT, https://sit.comune.falconara-marittima.an.it). The data were obtained through direct survey of green areas and environmental resources across the municipal area. Infrastructural system has been downloaded by the open-source street map (OSM) platform. Resident population and distribution dataset to define the user target related to green spaces are available on ISTAT website (2021). Then, we evaluated the level of usability by considering "the presence of structures capable of supporting people's activities" (Quatrini et al., 2019). Therefore, the "possibility and degree of enjoyment by citizens of a specific green area [...] (law no. 63/2015 Marche Region) was assessed through the spatial level of street furniture for each public green space (Pantaloni et al., 2022). This operation allows:

a) to check the suitability of the pedestrian pathway, especially for specific group of users. For instance, to consider benches for elderly people or adequate system of streetlight to guarantee public safety. This analysis intends to verify whether the public green areas served as street furniture. To do this, we evaluated the presence of street furniture along the pedestrian path through the application of the buffer method of 300 m diameter (by applying the Euclidean distance) from each public green area (Nicholls, 2001);

b) to verify the presence of street furniture within the public green areas to measure their multifunctionality with particular attention to the target of vulnerable users.

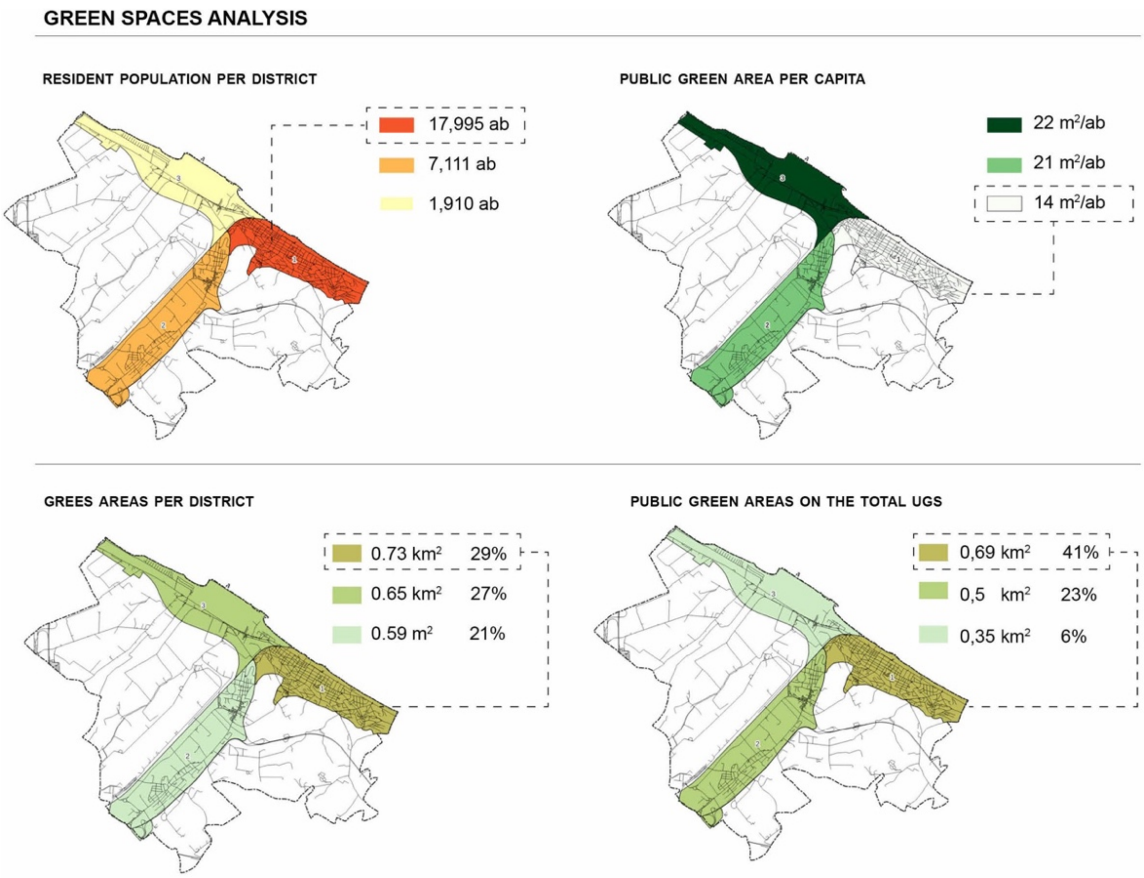

Fig.4 Analysis of green spaces in the three urban neighborhoods. The area of interest of district 1 "city center" is marked by the dashed line

Finally, we correlate the green areas with the resident population and the identification of potential users.

The overlay process in GIS environment allows us to perform geostatistical analysis for each district to define the network of pedestrian paths within the basin of potential users of the green space. Thus supported the proximity-based planning process for the provision of ecosystem services. Data show that, despite the highest percentage of public green areas on the total UGS, the district 1 "city center" has the largest number of resident population with the lowest percentage of public green areas per capita (m^2/inhabitant) and the highest percentage of public green areas on the total UGS (Fig.4). For this reason, we select district 1 "city center" as the focus area to cross-reference the network analysis with UGS and the resident population to define potential catchment area.

3.2 Focus area

On the total of 153 green areas surveyed in the "city center" (Tab.1) we applied a rapid evaluation methodology based on the correlation between a quantitative and qualitative indicator.

The first one is a quantitative indicator (binary type). Value 1 correspond to presence of street furniture; value 0 to the absence of street furniture. By applying this, n. 122 areas are not equipped, while the equipped area are 41. This means that the non-equipped areas are double those equipped, and number around 99,121 sqm with an incidence of 45% on the total public green areas.

Municipality land area	Urban area	Resident population*	Population density	Public green areas	Total green surface
[ha]	[ha]	[inh.]	[inh./ha]	[n]	[ha]
2,500	207.6	16,507	79.50	153	22.14

* source: ISTAT 2021

Tab.1 Focus area - general data

Then we applied a qualitative indicator type (multi-value) on the total of the 41 equipped areas to assess the provision of CES according to the level of usability. This correlates number of equipment and dimension of the green surface of each area. The indicators are assessed and ranked individually by assigning a value between 1 and 5, according to the criteria described for each level (1 low performance; 2 medium/moderate; 5 high performance) (Pantaloni et al., 2022), Tab.2.

	Established value	Number of equipment
Usability	1	1 - 4
	2.5	5-9
	5	≥ 10
Size		**Area [sqm]**
	1	< 200
	2.5	≥ 200; ≤ 5,000
	5	> 5,000

Tab.2 Indicators, evaluation criteria and level of estimation to classify green areas by qualitative approach

Applying this evaluation methodology, we grouped the 41 public green areas into three levels based on the connection between 'usability' and 'size' indicators (Tab.3).

Level	Threshold	Formula
L1	< 5	Nvalue + Dvalue
L2	≥ 5; ≤ 7.5	
L3	> 7,5	

Tab.3 Three levels according to threshold index. 'Nvalue' means the value assigned to usability indicator (number of equipment). 'Dvalue' means the value assigned to size indicator (green area surface)

This rapid assessment method based on multicriteria analysis allows us to select 8 areas in L3 level with a high performance of supply CES (Tab.4).

Level	Areas [n]	Surface [sqm]	Incidence on the total of equipped green areas [%]
L1	10	21,360	18
L2	23	28,120	22
L3	8	72,800	60

Tab.4 Three levels of usability. L1 (low performance), L2 (medium performance) and L3 correspond to a high provisioning capacity of CES

About resident population data, we grouped the 7 categories based on classification provided by ISTAT, National Institute of Statistics (updated to 2021, ISTAT) in 4 specific targets of the resident population (children <5 years; kids 10<x<15; adults 15<x<64, elderly 65<x<74, elderly >74 years. This is particularly relevant in the design of public areas for active ageing (Longhi et al., 2014).

Considering the definition of "usability" selected in this study, the identification of resident targets is based on the wide range of CES provided to citizen, that could be simplified with the evaluation of different categories of urban furniture (Tab.5).

Social milieu [targets]	**Age (range)** [years]	**Residents per age** [inh.]	**Residents per target** [inh.]	**Incidence on the total resident population** [%]	**Type of CES**	**Usability evaluation**
1	<5	535	1,081	6.55	Recreational, emotional	Safety spaces for sport and recreational activities for families (both children and adults)
	5-9	546				
2	10-14	681	10,459	63.36	Sense of identity, sense of community, sense of belonging to a place	
	15-64	9,778			Physical and mental health, well being, mental health	
3	65-69	1,055	2,193	13.29	Safety spaces, esthetic, and well being	Lightning system, benches and assisted pathways
	70-74	1,138				
4	>74	2,774	2,774	16.80	Safety spaces	
Total		16,507				

Tab.5 Focus area – usability of green areas related to resident population

Finally, we evaluate accessibility to the 8 areas selected by performing the network analysis, and cross-referenced data with resident population to define potential catchment area.

To do this, we considered a walkable distance of 300 m, 150 m and 50 m proximity thresholds, that have been crucial during the COVID-19 pandemic restrictions in place. The distance of 50 meters meets the needs of the elderly, who represent over 25% of the total residents in this area. Demographic data were divided by census sections defined by ISTAT. These correspond to the urban blocks defined by network systems (path and roads, Fig.5)

4. Results and discussions

At the city scale, network analysis allows us to define two spatial layers that represent the area covered by a walking distance of 5 minutes and 15 minutes (Bocca, 2024, Fig.6). Applying the 5-minute rule, 7.16 sq km are served by public green areas (equal to 28% of the municipal area), while 10.6 sq km access public green areas by applying the 12-minute rule (equal to 41% of the municipal area).

About the limitation, this method only considers spatial distance without space characteristics.

The district 1 "city center" measure the highest level of usability of public green areas according to the criteria selected. As we expected, parks are the most equipped areas where we register the highest level of usability (Fig.7).

The lower level of usability of the green areas located in neighborhoods 2 and 3 could be crucial for weak users, such as the elderly (Akhavan & Vecchio, 2018).

Fig.5 Number 41 public green areas in district 1 "city center". The eight L3 areas are marked in dark green

On the focus area, the results of network analysis demonstrate that just 61% of the residential population is served by 300 m rule. This means that, despite the urban planning compliance of the Land Use Plan with the minimum quantities of green standard for public facilities imposed by the Italian Ministerial Decree 1444/68 (9 sqm/inhabitant) and the Regional Law of Marche Region n.34/92 (12 sqm/inhabitant), almost half users are not served by public green spaces (Tab.6, Fig.8).

Accessibility radius [m]	**Urban blocks [n]**	**Potential users [inh.]**	**Incidence [%]**
50	55	3,620	21,9
150	100	7,429	45
300	143	10,096	61
Not served	100	6,411	38

Tab.6 Urban blocks and resident population served by the equipped green areas

Focusing on weak users, about 10% of elderly people of the total of resident population, 3% can use public greenery though a walkable distance of 50 m, while the over 75 are just 4% (Tab.7).
Moreover, the investigation highlights that about 10% of the over 65 does not have access to green facilities. This means that around 1,000 of elderly people are not able to access to urban services that are essential for

mental and physical well-being (WHO, 2017). These areas could be strategical for the effectiveness of active ageing and health policies (Tab.8, Fig.9).

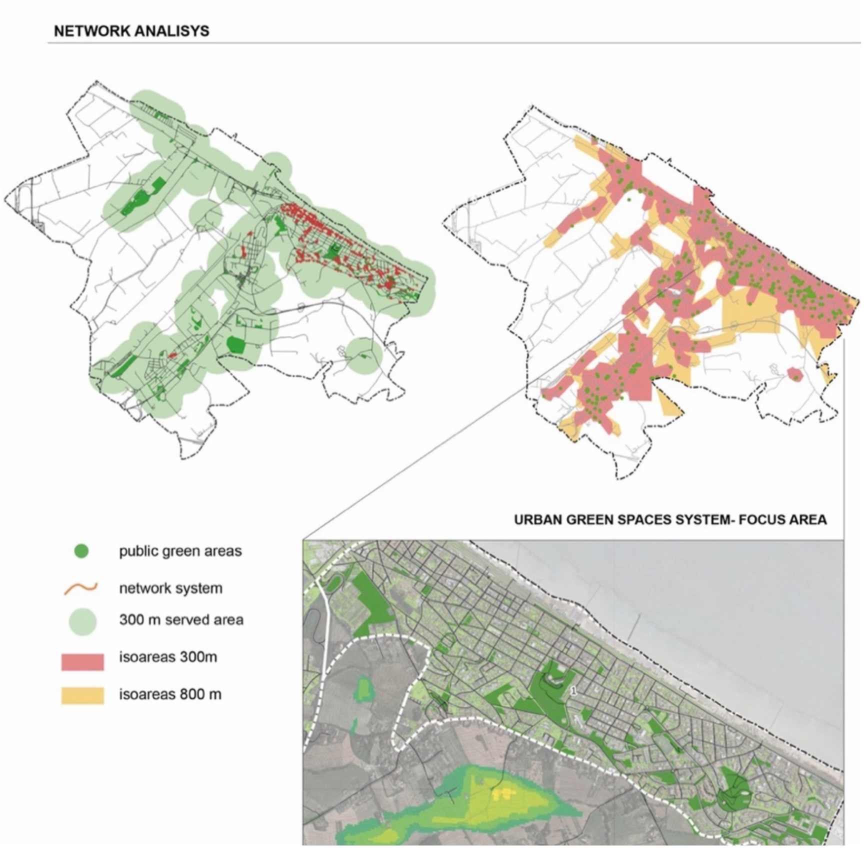

Fig.6 Network analysis developed based on isochronous method. The spatial layer represents the walkable distance to public green areas on 300 m (red) and 800 m (yellow) distances

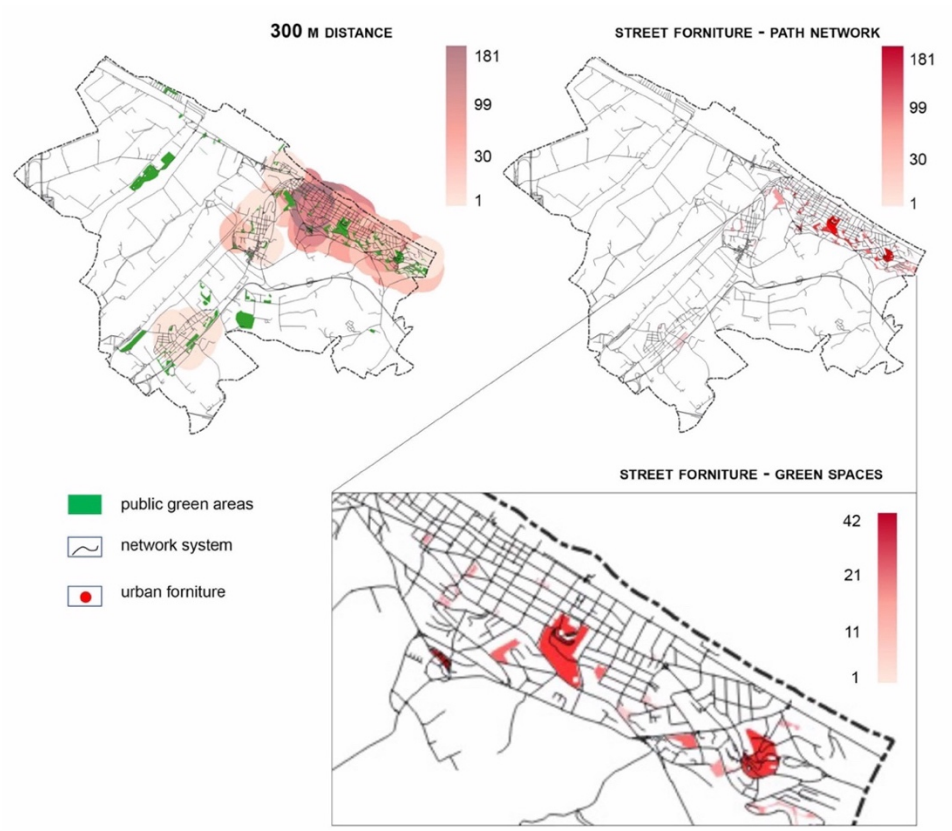

Fig.7 Evaluation of street furniture related to public green spaces using the buffer method

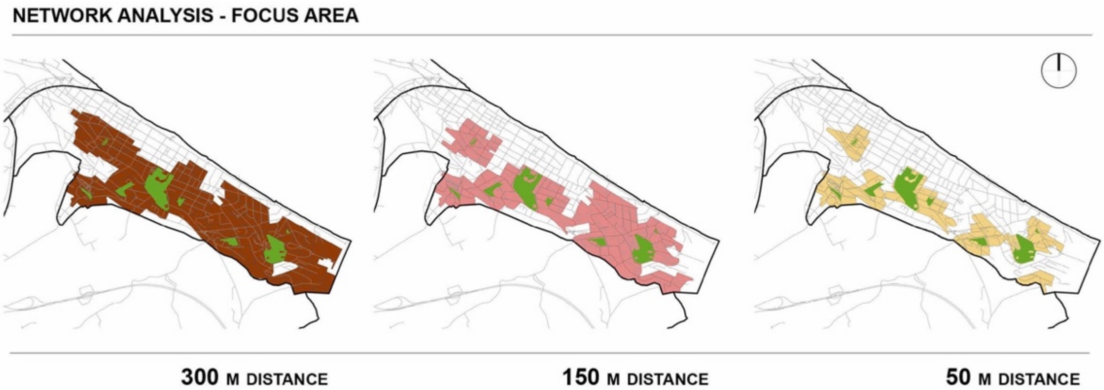

Fig.8 Urban blocks identified by spatial layers at the fixed distances

Social milieu [target]	Age [range]	Inh. per target [n]	Incidence [%]	Inh. per target [n]	Incidence [%]	Inh. per target [n]	Incidence [%]
		300 m		**150 m**		**50 m**	
1	< 5 5-9	10,395	62.9	7,648	46.3	3,722	22.5
2	10-14 15- 64	716	4.3	535	3.2	260	1.5
3	65-69 70-74	1,401	8.4	1,021	6.1	483	2.9
4	> 74	1,774	10.7	1,329	8.0	677	4.1

Tab.7 Catchment areas according to social milieu and walkable distances selected in this study

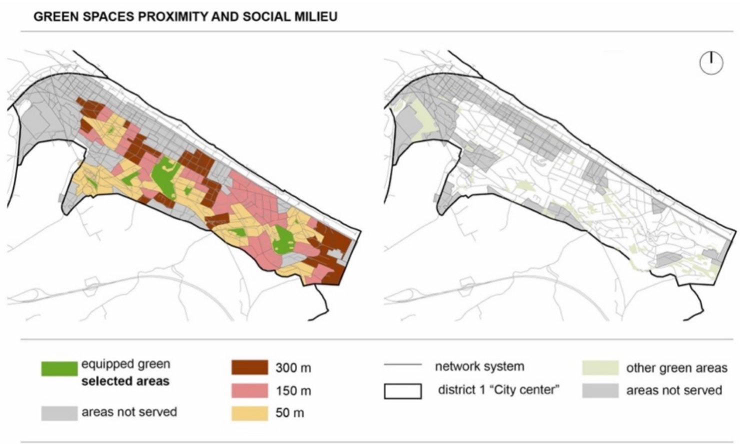

Fig.9 Potential catchment area. On the total of 398, 100 urban blocks are unserved by public green areas

Social milieu [target]	Age [range]	Inhabitants per age [n]	Inhabitants per target [n]	Incidence [%]
			300 m	
1	< 5 5-9	236 221	457	2.7
2	10-14 15- 64	290 3,872	4,162	25.2
3	65-69 70-74	375 417	792	4.8
4	> 74	1,000	1,000	6.0
total		6,411		38.8

Tab.8 Resident population unserved by public green areas

To summarize, in Falconara Marittima 16% of the green standards are implemented while 84% are not implemented by the Municipality according to the Ministerial Decree n. 1444/68 (to see Fig.2).
Results of the sectorial study highlights that on the 153 public green area just 41 are equipped, while 112 are not equipped. According to rapid evaluation criteria, 8 of these areas are classified as L1, while 33 are L2, L3.
The overlay between legal framework and the spatial layers deriving from the assessment of green spaces proximity permit to outline different scenarios, summarized in (Tab.9).
This conceptual framework can support the decision-making process to guide planning action based on the maximization of CES to better orient financial resources and improve the performance of urban ecosystems.

Green standard for public facilities (Ministerial Decree 1444/68)	**Green area type**	**Green spaces proximity**	**Planning action**	**Zoning variance**
Implemented green standards (16%)	Equipped green areas	L1	To maximize the provisioning of CES starting from the resident population target with specific needs.	X
		L2 – L3	Application of the diversified maintenance approach to critically select the public green area that needs to provide CES to citizens (based on rapid evaluation assessment, see "Material and Methods" section).	X
	Not equipped green areas	Excluded by the sectorial study	Confirm the existing green standard and invest money in actions to maximize the provision of CES based on the assessment of the proximity of green areas.	X
			The green areas do not meet the proximity criteria in the selected area. To be evaluated whether to provide a zoning variance on the green standard selected.	✓
Not implemented green standards (84%)		Not carried out	The green areas are outside the study area (or area of interest in the design phase). Further proximity studies on other areas of interest are necessary to foresee/exclude a zoning variance to confirm/not confirm the green standard selected.	✓

Tab.9 Planning action to guide the decision - making process and orient the urban policies and manage the green component of the Land use Plan

5. Conclusions

The work is part of a research project aimed at supporting public administrations in the assessment of 'performance' of green spaces and estimate ecosystem services application in urban and territorial planning (Rodas et al., 2018).
To perform geo-spatial models based on proximity evaluation of public green areas is essential to enhance the performance of urban environment based on citizen needs. It also helps to awareness on the gap between "quantitative" vs "performance-based" planning models (Cortinovis & Geneletti, 2020; Kendig, 1980) that taste qualitative evaluation criteria to guide planning process.
This study could be crucial in supporting the decision-making process of the green component of the Land Use Plan, defined as green standards for public facilities by the Italian normative framework. About the limitations of the study, the results depend to the availability of local data. For this reason, it could be carefully replicable to other similar Italian contexts. These analyses help local planners and politicians in using financial resources to update the role of the Land Use Plan: a) by selecting the urban green 'standards' endowments that respond

to citizen needs; b) by defining the zoning variance within the Land Use Plan to implement urban green facilities and boost green and blue infrastructure in the urban area.

All these actions could enhance the quality of the Land Use Plan and increase the quality of life in our cities.

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Image Sources

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Role of new technologies on pedestrian walking behaviour research

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Abstract

Walking behaviour has been considered one of the fundamental values of healthy, sustainable and liveable city concepts, various techniques for gathering, analysing and assessing data have been developed. More recently, new technologies have affected both individuals' walking experiences and how researchers assess walkability. Accordingly, traditional approaches have tended to be digitalized through technologies and systems such as Global Positioning System, Geographic Information System, video-based techniques, machine learning, laser scanning, Bluetooth, Radio Frequency Identification and so on. In this context, this research aims to understand the role of new technologies on pedestrian walking behaviour research for analysing/supporting walking behaviour. Through a literature review, the research firstly summarizes the literature on pedestrian behaviour in the public space, examining the potential and limitations of traditional tools. Secondly it analyzes studies examining pedestrian behaviour-walking-technology, to identify different types, general characteristics and interrelations of new technologies. By putting in relation the two domains, the paper reveals (1) the relations between technologies and traditional tools, (2) the role of these technologies in walking behaviour research and which of them are used to detect/assess/support specific walking variables and (3) limitations of these technological approaches. The results showed that technologies have different capacities in understanding walkability and collecting/measuring datasets. Usage of them depends on the scale and purpose; related studies often use them in an integrated form.

Keywords

Pedestrian behaviour; Walkability; Technologies.

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1. Introduction

Pedestrians' behaviour in public spaces and public life is essential to understanding urban dynamics and reading the relationship between human-built environments. After 1960, automobile-oriented urban space production, modernist planning principles and monotype urbanization were criticized, and the necessity of prioritizing the needs of pedestrians in cities and the importance of pedestrian-friendly urban-street life were emphasized (Calthorpe, 1999; Jacobs, 1961). In this direction, well-accepted studies have been carried out by experts such as Jacobs (1961), Whyte (1980), and Gehl (2007, 2010), and socio-spatial patterns related to pedestrian behaviour in urban space have been trying to be understood.

Since the 90s, rapidly developing technologies have changed pedestrian behaviour in a socio-spatial manner and diversified analysis/assessment tools of behaviours in public space through digitalization. With these shifts, the popularity of new technologies has increased in pedestrian behaviour studies, and computer-based tools, location-based approaches, and sensors have been used to replace or complete traditional tools for analysing/supporting walking behaviour. However, studies that subjective these are mostly scattered, and only a few of them deal with the effect of new technologies on pedestrian behaviour research holistically through different perspectives (Conticelli et al., 2018; Feng et al., 2021; Hanzl & Ledwon, 2017; Millonig et al., 2009). Accordingly, the paper would investigate the role of new technologies in walking behaviour research in public spaces by addressing the following research questions:

SQ1: What are the relations between technologies and traditional tools in pedestrian behaviour research?

SQ2: How are these technologies used in walking behaviour research, and what specific walking variables do they detect?

SQ3: What are the limitations of these technologies on walking behaviour research?

The final aim is to highlight the potential of these technologies in better supporting more walkable places planning and design.

2. Methodology

This research adopts a descriptive approach to analyze new technologies' role in walking behaviour research. After summarizing the traditional techniques to detect pedestrian behaviours in urban spaces, the research analyses the role of new technologies through the following three steps: 1) examining the relations between traditional tools and new technologies used in walking behaviour research, by reviewing similar articles/proceedings; 2) categorizing the different types of new technologies in pedestrian walking behaviour research against their usage; 3) trying to open up the limitations of these new technologies in walking behaviour research and how some researchers overcome them via models or multi-layered approaches.

3. Pedestrian walking behaviour research: an overview

3.1 The multifaceted relationship between pedestrian behaviour and public spaces

Pedestrian behaviour and public spaces are multidimensional issues in developing more vibrant urban spaces (Project for Public Spaces, 2012). Since the second half of the twentieth century, a wide range of different studies has been developed, highlighting the complex and multifaceted nature of pedestrian behaviours and public spaces relationship, dealing with the promotion of more walkable spaces. Accessibility and activity levels are some of the primary concerns to reach and use of public spaces that are studied through different approaches, such as observation of human behaviours or by classifying outdoor activities (Gehl, 2011) or by adopting more automated approaches. More recently, the new urbanism wave posed the attention also on, mix-use, human-scale environment, walkable neighbourhoods as key elements to consider for ensuring liveable places (Calthorpe, 1999; Fulton, 1996), and several cases have used new urbanism principles to provide strategies or evaluate neighborhoods, such as Zali et al. (2016)'s study.

In this context, creating walkable spaces requires an understanding of walking from a multi-layered perspective, but even walking behaviour is a complex mechanism in itself. It can be elaborated as a physical activity, sensorial and experiential issue or mode of transport (Mehta, 2008), and it has different types and characteristics such as utilitarian, social, and recreational, that affect needs, route choices and pedestrian attitudes (Choi, 2014). Based on the importance of walkability, evaluation of it has also been discussed and modelled by several researchers with different lenses. Overall, in the relevant literature, "walkability" is frequently studied with respect to three different lines: physical and built environment factors; perceptual approaches, subjective values and preferences; and human capabilities and quality of life (Blečić et al., 2020). Notably, Fonseca et al. (2022) listed main categories related to walkability and built environment attributes through a review: land use (density & and diversity), accessibility, street network connectivity, streetscape design, safety and security, pedestrian facility and comfort. Regarding these, several walkability assessment methods are conducted partly or holistically on different scales considering these approaches and represent walkability scores spatially, such as WalkScore, Walkshed etc. (Blečić et al., 2020).

This first overview highlights the complexity and the variety of factors and approaches that have been identified to investigate the correlations between walking behaviours and the urban environment. In the following sections we firstly consider the traditional techniques adopted for analyzing walking behaviours and secondly, we highlight the role covered by new technologies in supporting an effective investigation.

3.2 Traditional approaches for analysing pedestrian behaviour in public space

Analysing pedestrian movement is critical to understand urban dynamics and developing better mobility policies (Emmons, 1965). Pedestrian behaviours have been analysed for a long time through direct observations, interviews and questionnaires (Millonig & Gartner, 2008). Relevant to this matter, Gehl & Svarre (2013) listed tools based on observation such as counting, mapping, tracing, shadowing, looking for traces, photographing, diaries, test walking. Interviews are used to resolve individual patterns, motivational and perceptual factors etc. and questionnaires have advantages in terms of reaching large samples to capture habits, motives or intentions (Millonig & Gartner, 2008). On the other hand, experts mostly integrate different tools and techniques (Millonig & Gartner, 2008), depending on the research's purpose, budget, time, and local conditions (Gehl & Svarre, 2013, p. 22). In addition, Blečić et al. (2020) also mentioned that methodological preferences are affected by the objective and subjective nature of variables in walkability assessments. Although manual techniques and statistics have been widely used since the 60s and have many advantages, they also have some limitations in examining and controlling data quality and representation, in understanding crowd movement (Stanitsa et al., 2023) or in effectively managing a large amount of data (Gehl & Svarre, 2013). Detailed explanations about the advantages & disadvantages of traditional tools are listed in Tab.1.

Traditional Tools	**Advantages**	**Disadvantages**
Counting	Provides statistical data, supports comparisons, allows observer to detect other properties about pedestrians (Gehl & Svarre, 2013). Simple process, effective in temporally limited and small-cross sections (Bauer et al., 2009).	Time consuming, labour intensive to analyse (Gehl & Svarre, 2013), counting accuracy may differ based on observer and complexity (Bauer et al., 2009).
Mapping	Supports plotting activities, captures well staying activity patterns, works like aerial photo (Gehl & Svarre, 2013)	Labour intensive, observers can be distracted during marking process which effect the data accuracy (Gehl & Svarre, 2013).

Traditional Tools	Advantages	Disadvantages
Tracing	Determines movement patterns, gather information about walking sequence, choice direction flow etc. (Gehl & Svarre, 2013).	It is a representation, not exact; dividing space into small zones can be required to analyse manually (Gehl & Svarre, 2013).
Tracking/ Shadowing	Unaware pedestrians support capturing natural use of public space (Millonig & Gartner, 2008; Stanitsa et al., 2023).	Manuel shadowing has limited sample and accuracy (Bauer et al., 2009).
Photographing	Support before/after comparisons, it can expand observers' perspective, provides time-lapse evidence to observation (Gehl & Svarre, 2013; Hanzl & Ledwon, 2017).	Provides an instant view if it is not repetitive, this could be insufficient data for detecting pedestrian movements.
Diaries	Different types of diaries (kept by observer, trip) have their own potentials (Gehl & Svarre, 2013; Millonig et al., 2009).	Diaries may depend on the observer's selective judgments.
Test Walks	Provides an understanding of real-time/distance dynamics, good for detecting waiting times, potential obstacles etc. (Gehl & Svarre, 2013).	Observation in motion can become less systematic and hard to capture overall movements in a public space.
Interviews	Supports capturing underlying motivations, choices, individual patterns (Millonig & Gartner, 2008)	Depends on response accuracy, distortions in self-assessment (Millonig & Gartner, 2008).
Questionnaire surveys	Reaching large samples, being low-cost, capturing motives, intentions, habits (Millonig & Gartner, 2008)	Depends on response accuracy (Millonig & Gartner, 2008), standardized nature may limit capturing insights.

Tab.1 Advantages and disadvantages of traditional approaches for analysing pedestrian behaviour in public space

3.3 The role of new technologies on pedestrian walking behaviour research

Information and Communication Technology (ICT) and walking behaviours: main application domains

Concerning urban space and human behaviour, developing technologies have affected our daily life routines and public space uses, and have hybridized relations between the city and citizens (De Souza E Silva, 2006). Consequently, observation and other research techniques regarding pedestrian behaviour analysis have tended to become more digitalized, with the development of ICT and other tools (Gehl & Svarre, 2013). According to Conticelli et al. (2018) walkability-oriented application areas of ICT can comprise three main domains: real-time information and data gathering, assessing and measuring walkability, supporting walking behaviour.

- *Data gathering/collection* is a fundamental but complex task for understanding walking presence and patterns. Several studies highlight the added value of using new technologies to increase data richness, validity and quality in capturing variables such as pedestrian numbers, duration and length of the journey, pedestrian flows, etc;
- *Assessing/measuring walkability* is essential to urban decisions and design processes. Accordingly, ICT and Geographic Information Systems (GIS) have an essential impact for automatizing the calculation of assessing, and measuring systems;
- *Supporting walking behaviours:* walking habits of pedestrians have changed, especially with smartphones. Even though it is stated that these devices are seen as a distraction in terms of pedestrian safety (Siuhi & Mwakalonge, 2016; Reynolds Walsh et al., 2019), there is also evidence that they can support the walking experience, favouring this means of transport. Mobile applications especially have lots of potential for pedestrians, who use mobile apps for route planning connected with distance, time predictions, optimal route choices, navigation, wayfinding, travel information (Conticelli et al., 2018; Siuhi & Mwakalonge, 2016), encouraging pedestrian mobility.

ICT and walking behaviours: main technologies

As anticipated, technological advancements have directly affected analysis in pedestrian studies data collection and assessment/measuring manners (Conticelli et al., 2018). In the data-gathering process, Global Positioning System (GPS), Global System for Mobile Communications (GSM)/ Universal Mobile Telecommunications System (UMTS), Bluetooth, Wireless Local Area Network (WLAN), Radio-Frequency Identification (RFID), and laser scanning, are tools that come to the fore and are used for counting or tracking purposes with various devices (Conticelli et al., 2018; Hanzl & Ledwon, 2017; Millonig et al., 2009). In addition, mobile phones (MP) integrated with other technologies (Toch et al., 2019) are also another popular, cost-effective product to collect data on variables such as number, mobility, speed, and distance of pedestrians (Siuhi & Mwakalonge, 2016). In terms of assessment/measuring, GIS based applications are one of the most popular tools (Conticelli et al., 2018; Wang & Yang, 2019); also, lately, technological approaches toward machine learning (ML), and computer vision improve urban analytics by analyzing a massive amount of data; and these improvements also open new perspectives in walkability assessment studies such as using of street-level imagery (Biljecki & Ito, 2021; Telega et al., 2021). Related to these, some experts analyzed technologies that listed up in considering their effects on pedestrian behaviour or relation to walkability. For example, Millonig et al. (2009) considered technologies through pedestrian behaviour monitoring abilities, and Bauer et al. (2009) examined them through measurements of pedestrian movements related to counting/tracking. Hanzl & Ledwon (2017) detailed technologies used to analyze human behaviour in public spaces, and Conticelli et al. (2018) showed available technologies for walkable cities. In the following part a detailed analysis of the most relevant technologies used in pedestrian behaviour research are analyzed in detail, with the aim to highlight main features and applications in analysing and supporting pedestrian mobility.

<u>Global Position System</u>

Global navigation satellite system (GNSS) is the general definition for satellite-based position determination systems, and GPS is the system owned by USA. Systems that provide outdoor high-frequency and continuous location information are often essential to pedestrian mobility technologies, as they can be served on personal mobile devices (Millonig et al., 2009). It is common for geospatial technologies to work integrated with many different technologies such as sensors, wi-fi, and Bluetooth, to raise data accuracy (Hidaka et al., 2019; Rout et al., 2021). They are effective in providing real-time data collection and are a good option for outdoor detections (Alia et al., 2022), but data from GPS is often raw therefore needs to be further elaborated and then mapped (Wielebski et al., 2020).

a) Relations with traditional tools: GPS has been used in many studies to collect data (Hahm et al., 2019) through counting and tracing spatial mobility patterns of pedestrians, for the short or long term in different areas, from the urban to the neighbourhood scale, together with different devices (Feng et al., 2021).

b) Relations with walking behaviour research: GPS (with receivers, smartphones, lodger etc.) is used for data collection purposes in pedestrian behaviour studies (Hahm et al., 2019; Moiseeva & Timmermans, 2010). In addition to that, GPS-based applications in smartphones also support walking behaviour in terms of wayfinding, route planning, etc. Depending on receiver and signal quality, GPS can provide information about route, distance, duration, travel areas, mobility classification (Moiseeva & Timmermans, 2010; Rout et al., 2021). Several cases can be found in the literature related to GPS experiments with different themes considering walking behaviour. For instance, Hahm et al. (2019) conducted GPS experiment to understand choice of walking routes in the retail district; Khanal et al. (2019) used a GPS-based mobility survey to reveal the walking behaviours of older adults; Yun et al. (2018) used data from GPS-based smartphone app to determine urban walking tourist’ spatial distributions and seasonal differences between them with integrated with other techniques, and so on…

c) Limitations: Obstructed satellite signals, weak signals, shadows in urban areas and other technological limitations can affect data accuracy (Millonig et al., 2009; Moiseeva & Timmermans, 2010). Although it is used to monitor pedestrian mobility, GPS records may have more errors in high-density environments encircled by tall buildings (Hahm et al., 2019, p. 5). The uncertainty of GPS data may require the use of additional methods (Hahm et al., 2019), and some smoothing techniques can help to fix measurement errors (Hidaka & Yamamoto, 2021). In studies that often relate to city-scale big and anonymous data, limitations on travel type and travel purpose detection are highlighted, as users cannot be identified (Basu & Sevtsuk, 2022).

Geographical Information System

GIS, related functions and data are essential tools for planning practices in terms of analytics and performing tasks through elaboration of different kinds of geospatial data. In the 60s, the first examples of GIS were used; after the 90s, services that included GIS functions, such as web-based services, aerial photography, and three-dimensional views, became more widespread. Nowadays the ongoing process involving GIS pushes towards an integrated use of GIS and other technologies, especially GPS, Internet, Remote sensing etc., thus increasing its potential and supporting its use in different fields (Drummond & French, 2008).

a) Relations with traditional tools: GIS has advanced interfaces for coding, processing and analyzing spatial data. Accordingly, the use of GIS-based interfaces for keeping records, mapping of the observation processes has become more common in field studies of human behaviour in public spaces (Ghavampour et al., 2017).

b) Relations with walking behaviour research: GIS techniques are objective tools that can ensure to assess walkability (Wang & Yang, 2019). Some parameters that are widely examined to assess walkability through GIS can be listed as density, land use, accessibility of urban services/green facilities, street layout and so on (Lee & Talen, 2014; Telega et al., 2021). Moreover, 3D GIS techniques can be useful for street-level walkability urban design assessments (Wang & Yang, 2019). In addition to these, GIS-related interfaces (mobile or web-based) allow the collection of various types of data by multiple users. Relevant to these, several examples can be found in the literature related to walkability and walking behaviour through GIS tools; for instance, Telega et al. (2021) detailed methods to measure walkability with GIS and applied their proposal for Krakow; Blečić et al. (2014) introduced Walkability Explorer which is a walkability evaluation tool that contains GIS features; Manfredini & Di Rosa (2018) used GIS tools to reveal spatial accessibility for the elderly through pedestrian road networks in Milan; Al Shammas et al. (2023) proposed GIS-based algorithm for walking route planner considering specific pedestrian comfort parameters, within some limitations; Laatikainen et al. (2019) collected data about older adults travel behaviour with public participatory GIS (PPGIS) via an online mapping survey and post-processed them with additional techniques.

c) Limitations: GIS-based walkability assessments perform depending on data availability, accuracy and reliability. On the other hand, many cities still suffer from a lack of up-to-date comprehensive datasets (Lee & Talen, 2014).

Video-based (VB) methods

VB techniques include gathering visual data via camera(s) and are often associated with computer vision. Automated video systems in pedestrian research have advantages in capturing the natural mode of pedestrians, data accuracy & consistency (Alsaleh et al., 2018). Borges et al. (2013) categorise video-based human detection methods into three groups: appearance-based, motion-based and hybrid. Relatedly, VB methods can be used for action recognition, gait analysis, defining trajectories, and interaction analysis related to pedestrian behaviour, and several models/algorithms/datasets can be used to conduct and improve the abilities of analysis (Borges et al., 2013).

a) Relations with traditional tools: Video-based approaches have already been used for observational studies to understand public space dynamics for a long time manually. However, in the last two decades, they have tended to be automated with computer vision techniques. Via video-based monitoring, counting and tracking of pedestrians can be performed within some limitations (Malinovskiy et al., 2008).

b) Relations with walking behaviour research: It can be used for data collection purposes in pedestrian behaviour studies in relation with application areas and to detect pedestrian numbers, pedestrian trajectories, etc. Several studies are conducted through video-based analysis to understand pedestrian walking behaviour by integrating additional techniques or algorithms based on research purposes. For instance, Willis et al. (2004) used video-based techniques with motion software and other measurement techniques to understand the microscopic movement patterns of pedestrians and some other features related to their walking behaviours; Alsaleh et al. (2018) analysed the impacts of cell phones on walking behaviour with using automated video analysis with using computer vision techniques; Liang et al.(2020) examined effects of climate on pedestrian walking through video-based observational study that use computer vision technology.

c) Limitations: Viewing angles, environmental conditions, positioning, calibration problems can affect analysis and data accuracy (Millonig et al., 2009). Different techniques and algorithms for pedestrian detection and tracking have their own constraints as mentioned in Malinovskiy et al. (2008)'s study.

Machine Learning Approaches (ML)

Interest in ML methods in urban studies is rising thanks to their ability to perform various tasks through a large amount and different types of data. ML methods (supervised/unsupervised) can be differ based on descriptive and predictive capabilities and different models can be used to analyse or model pedestrian mobility through different datasets (Toch et al., 2019).

a) Relations with traditional tools: ML can perform analyses for detection of pedestrian volume (Chen et al., 2020) or tracking (Toch et al., 2019) through location-based or visual data (photo/street view etc.) obtained/integrated with different technologies (Wifi, GPS, Bluetooth, GIS etc.).

b) Relations with walking behaviour research: In this research, ML approaches are considered one of the tools that support walkability assessment/measurements, but it is an emerging area with the potential to evolve. Literature concerning ML and walking show that depending on the dataset's characteristics. Several operations can be served to support walkability assessments through different models. For example, Blecic et al. (2018) use trained images by humans to understand perceived walkability, Zhou et al., (2019) use deep learning techniques to segment the physical environment through street view imagery and score visual walkability. Similarly, some other studies use street imagery through ML to detect pedestrian volume (Chen et al., 2020), to understand visual enclosure for street walkability (Yin & Wang, 2016) etc.

c) Limitations: Not all machine learning models perform in the same way, this depends on the task to be undertaken (Blecic et al., 2018); accordingly, the selection of the right ML tool for a given task can be challenging (Toch et al., 2019). Data bias, over/underfitting issues, and lack of data are some limitations that may occur related to ML approaches.

Augmented Reality (AR)

Augmented Reality is a technology that creates virtual views in real scenes (Isoyama et al., 2021; Mahapatra et al., 2023; Narzt et al., 2006), and lately its usability with different devices has increased. On the other hand, AR can positively/negatively affect pedestrians' walking behaviour depending on display positioning and characteristic of the content created (Isoyama et al., 2021). It has different indoor applications such as displaying routes in museums, commercial stores (Isoyama et al., 2021), and outdoor, as walkable AR experiences or games (Reilly et al., 2020), guides, navigation (Dong et al., 2021) etc. It works with other technologies such as Bluetooth, GPS etc (Amirian & Basiri, 2016; Mahapatra et al., 2023).

a) Relations with traditional tools: AR is still used in more experimental ways in research dealing with pedestrian behaviours in urban spaces. Most studies are conducted through outdoor experiments in which test-walk groups use devices/software to understand AR's effect on walking/perceiving/playing.

b) Relations with walking behaviour research: Although AR can be used in several contexts, it is often associated with pedestrian navigation systems in pedestrian studies (Amirian & Basiri, 2016; Mahapatra et al., 2023; Narzt et al., 2006), supporting walking behaviour in terms of route, wayfinding, and guidance. Relevant to these, Dong et al. (2021) tested the difference between 2D digital maps and AR-based navigation to understand the usability of AR navigation, considering wayfinding and spatial memory issues.

c) Limitations: AR has still not reached its full potential in the context of urban applications. Different viewing angles and resolution capacities in some devices and positioning problems may limit the user experience (Isoyama et al., 2021).

<u>Laser Scanning</u>

"The laser scanner measures distances of nearby objects by emitting eye-safe laser beams at controlled directions and computing their time of flight" (Shao et al., 2007, p. 2174). Lately, interest in laser range scanners is rising related to tracking issues, and they have advantages in measurements and position determination (Shao et al., 2007). Some studies use multiple scanners for better results, and data gathered by various clients can be integrated to cover larger space (Shao et al., 2007). Relatedly, several algorithms/techniques have been proposed by experts to support the process of pedestrian detection and tracking process based on research purposes.

a) Relations with traditional tools: Pedestrian detection, counting and tracking can be done using laser scanning data (Bauer et al., 2009; Shao et al., 2007; Xiao et al., 2016). However, these practices via laser scanning may require different implementation procedures depending on scanner type, positioning, scene etc. (Bauer et al., 2009).

b) Relations with walking behaviour research: Laser scanners are mostly used for data collection, and there are several approaches that use those data in training models or supportive purposes in walking behaviour research. For example, Xiao et al. (2016) have proposed an algorithm for simultaneous detection and tracking of pedestrians using data captured with panoramic laser scanning and found out that these kinds of approaches can be efficient for flow estimations; Shao et al. (2007) have focused on detection and tracking of pedestrians in crowd scene using laser range scanners; Gate & Nashashibi (2009) are interested with pedestrian detection with laser scanning in dense urban spaces from moving vehicles; Maruyama et al. (2016) has created 3D environment models using laser scanners to support walking simulation.

c) Limitations: Laser scanners are costly, especially in scenarios requiring multiple scanners, equipment may not be affordable (Hanzl & Ledwon, 2017; Millonig et al., 2009). Also, bad weather conditions can affect devices in outdoor experiments, and the detection range may not be sufficient (Kidono et al., 2011) depending on the tasks.

<u>Bluetooth</u>

Bluetooth is used for data exchange between devices located in short-distance, therefore has a big potential in proximity-based detection related to pedestrian behaviour (Hanzl & Ledwon, 2017), and ensuring information. It is used for "device-device communications" with several sensors, internet, smartphones etc. (Malinovskiy et al., 2012, p. 137), and it has passive and active forms. It can support real-time data collection in pedestrian studies integrated with other technologies, like Wi-Fi systems and is considered a low-cost approach for pedestrian detection (Kurkcu & Ozbay 2017).

a) Relations with traditional tools: Bluetooth has potential in small-medium scale analysis in pedestrian studies; it can perform counting and tracking within limitations (Millonig et al., 2009).

b) Relations with walking behaviour research: Bluetooth can be used for data collection purposes in pedestrian oriented studies (Kurkcu & Ozbay, 2017; Malinovskiy et al., 2012). Sample sizes can be limited, and the travel time of pedestrians can be calculated through positioned devices (Malinovskiy et al., 2012). Accordingly, different studies have benefited from Bluetooth sensors related to their research dynamics. For instance, Angel et al. (2023) have been interested in the impact of policies during the pandemic on walking behaviour using datasets related to pedestrian movements documented via Bluetooth sensors; Malinovskiy et al. (2012) have conducted outdoor experiments to analyse pedestrian travel via Bluetooth; Davies et al. (2009) have benefited from Bluetooth in their experiments to support the interaction of users with public screens in a campus and so on.

c) Limitations: Users that actively use Bluetooth are limited and thus can result in insufficient sample size. In the experiments, privacy and bias concerns may exist (Malinovskiy et al., 2012).

<u>Radio-Frequency Identification (RFID)</u>

RFID is an AUTO-ID technology (Pang et al., 2010, p. 389) and an intrusive localization method for pedestrian studies (Bauer et al., 2009, p. 341), supporting identification and tracking. It works through tags and readers via different objects (smart cards, labels, wristbands etc.), and has passive and active tag types (Bauer et al., 2009; Chen, 2010; Pang et al., 2010), can be used with several technologies like Wireless sensors, GPS, etc. and has advantages like being low-cost, easy to use, verifying and providing automated real-time information. In urban planning, it is used to detect pedestrian movements, and understand transit behaviour, and vehicular movements (Pang et al., 2010).

a) Relations with traditional tools: RFID is used for pedestrian counting and tracking both indoors and outdoors (more experimental phase) within some limitations (Hanzl & Ledwon, 2017; Millonig et al., 2009).

b) Relations with walking behaviour research: Usually, it is used for data collection purposes in pedestrian behaviour research. There are different experiments in the literature, from "child localization system" in a theme park with RFID and wireless sensors (Chen, 2010) to "positioning estimation" for the visually impaired people (Yamashita et al., 2017). Related tags can support the determination of pedestrian density, movements, and flows (Conticelli et al., 2018).

c) Limitations: Privacy concerns are the most relevant limitations, and these problems must be fixed before the implementation of research experiments (Conticelli et al., 2018). Costs depend on RFID types and numbers (Pang et al., 2010).

<u>Wireless Local Area Network (WLAN)</u>

WLAN systems are networks that can connect several devices; in general, they offer access to the internet with access points (Santi, 2012). Relatedly, Conticelli et al. (2018) have mentioned Wi-Fi, one of the most common WLAN types, considering its linkage with smart pedestrian mobility systems, and Stanitsa et al. (2023) have addressed potential of data gathered from Wi-Fi tracking thanks to its cost-effectiveness and wide coverage.

a) Relations with traditional tools: WLAN data can be used for counting and tracking purposes in pedestrian studies within some limitations (Hanzl & Ledwon, 2017).

b) Relations with walking behaviour research: WLAN is used for data collection purposes in pedestrian studies (Millonig et al., 2009). In relation to these, Stanitsa et al. (2023) have tabulated variables used in their study, and the ones based on Wi-Fi tracking sources are listed through coordinates, date and time, time spent, distance, and walk speed. Also, Feng et al. (2021), in their study reviewing data collection methods considering pedestrian behaviour, investigated various research that used Wi-Fi. In addition, pedestrians can reach other services via these networks, so it indirectly affects walking behaviour with data exchange based on content.

c) Limitations: Position accuracy is one of the main disadvantages in Wi-Fi based location approaches, so research purposes must be considered accordingly and signal accuracy can differ in space (Stanitsa et al., 2023), gathered data may need processing procedures based on task.

Global System for Mobile Communications / Universal Mobile Telecommunications System (GSM/UMTS)

Mobile device usage is increasing, which triggers an understanding of the potential use of GSM/UMTS data. It is considered one of the alternatives for location data sources within limitations.

a) Relations with traditional tools: GSM/UMTS data and related localization methods can be used for approx. counting, and tracking. Tracking ability may not perform well in public space studies related to accuracy (Hanzl & Ledwon, 2017) but its capacity can be raised with custom applications or integration with other technologies such as GPS, Wifi etc.

b) Relations with walking behaviour research: It usually provides the data collection phase of walking behavior research. Feng et al. (2021, p. 5) have highlighted the role of GSM data in detecting mobility patterns, crowd densities, described in some studies. In addition, Sohn et al. (2006) show that GSM data can be used for mobility detection in a way integrated with custom applications.

c) Limitations: Regarding cell-based approaches, the data obtained depends on user activity, access permissions, and cell network providers and network density; user privacy and security are critical issues (Millonig et al., 2009). Relatedly, Toch et al. (2019) have mentioned that call detail records can not perform well in analyzing small-scale movements.

	Relation with traditional tools	**Analyze (data collection / assess) & Support**	**Walking / walkability indicators that capture**	**Limitations**
GPS	Counting, tracking	Analysis/mostly data collection, supporting walking behaviour*	Route, distance, duration, speed, time stamps, location…	May need additional smoothing techniques for signal interruption…
GIS	Mapping, Questionnaires*	Analysis/mostly assessment,collection*, supporting via GIS-based applications*	Walkability assess/ land use, accessibility of urban services& facilities, street layout...	Lack of data problems in terms of availability and accuracy ..
VB-tec.	Counting, tracking	Analysis/mostly data collection	Walking/ gaits, activities, routes …	Depending on viewing angles, environmental conditions, calibration, etc.
ML	Use datasets to count and track	Analysis/mostly assessment	Walkability assess/ built environment & perceptual features	Expert knowledge, different models for different tasks…
AR	Test walks	Supporting walking behavior*	Support walking in terms of route, wayfinding, guide…	Limited experience, changing attitude depends content/ positioning…
Laser Scan	Counting, tracking	Analysis/mostly data collection	Walking/ time stamps, location related to device…	Costly, affected from environmental conditions, may need multiple device use..
Bluetooth	Counting, tracking	Analysis/mostly data collection	Walking/ travel time…	Active users can be limited, privacy and bias concerns…
RFID	Counting, tracking	Analysis/mostly data collection	Walking/density, flows…	Privacy concerns etc.
WLAN	Counting, tracking	Analysis/mostly data collection	Walking/ time stamps, distance…	Signal accuracy, may need multiple access points etc.
GSM/UMTS	Counting, tracking*	Analysis/mostly data collection	Walking/ pedestrian density, time stamp…	Depending on user activity, permissions, network providers, privacy issues ...

* may need additional technologies/ interfaces

Tab.2 Summary of technologies related to pedestrian walking behaviour studies

Technologies differ in their role in pedestrian walking behaviour research. In that sense, GPS, VB-tech, laser scanning, Bluetooth, RFID, WLAN, and GSM/UMTS are mostly related to data collection; counting and tracking purposes within limitations; as mentioned in (Hanzl & Ledwon, 2017; Millonig et al., 2009); GIS and ML perform/assist walkability assessments depending on the task; AR, GPS or GIS-based applications can be used to support walking behavior (Tab.2).

4. Conclusion

Within the scope of this research, the relationship between different technologies and traditional tools for analyzing and supporting pedestrian behaviour, has been examined in terms of usage patterns, and limitations thus giving an updated and comprehensive perspective. Similar reviews have been undertaken but they are few and partial: this review goes beyond by including relevant technologies, such as GIS, machine learning, and augmented reality technologies that can support pedestrian behaviour and walkability analysis. As a result of this paper, it has been detected that technologies have different capacities in understanding the dynamics of accessibility & walkability and collecting/measuring data sets that are difficult to cope with manual tools. Usage&choice of them mainly depends on the scale and purpose of the research. Therefore further research is needed to understand the real potential and usability of these tools, thus easing their usage and supporting users and practitioners in selecting the most suitable and relevant ones depending on their skills and research and application purposes.

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Coastal roads atlas. Reshaping daily infrastructures for coastline adaptation

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Abstract
The widespread poor quality that characterizes many cities and urbanization today is often related to the outdoor spaces. These conditions are common situations in many contexts of our country but are intensified where spatial inequality and environmental vulnerability converge. Although declined in different territories these situations have at their center the complex space of the road. The road system not only contributes significantly to climate change but is also the main victim of the consequences related to these changes.
The research investigates the role of the roads and parking spaces, interpreted as the main background of our everyday lives, in facilitating socio-ecological transition of most fragile territories. Particular attention is paid to the different vulnerabilities of Italian coastline and to the ways in which adaptation measures can be implemented to mitigate risks.
The initial analyses are focused on developing methods to measure and evaluate the climatic, geophysical, and socio-economic vulnerabilities of coastal roads, which are rendered, through aggregated maps of quantitative and qualitative indicators, in an "Atlas of Coastal Roads". The Atlas is conceived as an operational tool, able to guide stakeholders to develop national and place-specific interpretations.

Keywords
Coastal roads; Public spaces; Socio-ecological transition; Adaptation; Atlas.

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1. Introduction

The widespread poor quality of living that characterizes many cities and urbanization today is often closely linked to what lies outside the domestic space. On the one hand, the lack of common spaces in the neighborhoods, often reduced to mere parking spaces for cars, often overabundant and lacking in overall design and quality, as well as the lack of care and ordinary maintenance of the same. On the other hand, the lack of efficient collective integrated mobility services and other commons, when present, are inaccessible and detached from the surroundings. These are common situations in many Italian contexts, which are intensified where conditions of fragility (social, economic, environmental) are concentrated, and where spatial inequality and environmental vulnerability converge. These conditions are declined in different territories and ways, but often have at their center the complex space of the road: carriageways, pavements, cycle and pedestrian paths, car parks, open spaces, squares, and abandoned-waste spaces (Lanzani et al., 2021).

The research program intends to investigate the street space as the main background of everyday life and as an integral part of a strategic vision for cities and territories. By reinterpreting the road as a "pervasive" (Secchi, 1989) infrastructure that can shape the quality of the environment and living, the research emphasizes its great potential to experiment with an overall socio-ecological transition of the territories.

What new factors can we introduce today about the image of the road, or better, "the vision of man in his 'natural' context: the dark grey parterre, background of action, but also crossing, journey, metaphor of knowledge" and about the asphalt as the "new crust of the earth", fil rouge of the most consistent metropolitan transformations since the late 19th century industrial city evolution (Zardini, 2003)? This is the first research question that will be explored in depth.

The general research question on infrastructure for daily living was referred to the Italian coast, affected by significant anthropogenic pressure and the impacts of climate change. Fragilities and opportunities were analyzed within key buffers, including coastal freeways and urban roads which intersect with various geomorphologic and settlement structures along the sealine.

One of the main goals of the research, described in the second part of the article, is elaborating a trans-scalar Atlas of national Coastal Roads, useful to study the current and future connections between coastal roads and environmental, demographic, socioeconomic factors. It provides both quantitative and qualitative insights, highlighting the critical issues and potential opportunities in different national contexts. The Atlas is conceived as an operational tool, able to guide stakeholders in developing national and place-specific interpretations, orient policies and projects toward a systemic approach, empower sustainable actions, and address future scenarios.

2. Everyday life infrastructure. Interpretations from the past

The invention of the private car in the late 19th century represented the most significant technological change in urban transport since the introduction of the locomotive (Eco, 2012). Its diffusion revolutionized the way we move within the city and the territory, profoundly influencing its conformation. Although the car has played a predominant role in the development of cities throughout its history (Adams, 1970), roads, car parks and their related spaces have been subject to few innovations, which have tended to be technological rather than spatial. In some cities, the footprint of the road and parking network covers more than a third of the land. Surprisingly, this omnipresent network has received minimal attention since the 1950s (Joseph, 2015).

In fact, some famous interpretative efforts in the literature of urban geography and sociology and urban planning and design refer to these two main functions of the street.

The first is the street as "public space" for people in the city, to observe, or lose oneself (Debord, 1956), a space for meeting. At the beginning of the 1960s, in the United States, the street became a central question in Jane Jacobs' writings for Architectural Forum since 1952 to 1962 (Jacobs, 1958 & 1961). The collaboration between the Massachusetts Institute of Technology (MIT) and Harvard University led to the Joint Center for

Urban Studies series, which will publish some important books dedicated to the street and to the city (Rossi, 2017). Lynch examines the road as a visual experience to investigate the consequences between urban pattern, function and image (Lynch, 1961 & 1964). Serge Chermayeff and Christopher Alexander investigated the relationship between the structure of the city and the influence on its inhabitants (Alexander, Chermayeff, 1964). The anthology *On Streets* collects the results of studies begun in 1970 by a heterogeneous group of researchers examining the semantic, structural, historical and social aspects of the street and interpreting it as public space in the contemporary city, rather than as flow and traffic space (Anderson, 1978). Along the same line of thought are the books *Livable Street* (Appleyard, 1981), and *Life Between Buildings* (Gehl, 1987).
The second meaning attributed to the road coming from history is linked to "motion" that is recalled in Lynch's "channels of movement" (Lynch, 1961 & 1964) or in the freeways of "Autopia", where Angelenos spend a large part of their lives, and for this reason, the road system is one of the ecologies of Los Angeles identified by Rayner Banham, who learns to observe the city through the windshield and rear-view mirror of a car: «Just as ancient generations of English intellectuals learned Italian to be able to read Dante in the original, I learned to drive a car to read Los Angeles» (Banham, 1971). In *Learning from Las Vegas*, Robert Venturi offers an effective description of how urban spatial form is determined by the road network and how this influences the access to most places, such as residential buildings, shops and services (Venturi et al., 1977).
To range over other fields of literature and art: "un' autostrada non è solo un' autostrada" is a quote from *Le città invisibili* (Calvino, 1972), which suggests that a highway, is more than just a road for cars, but it's a part of the landscape and it has an impact on the people who use it and vice versa.
Robert Smithson defined the roads as ready-made artwork on a territorial scale, as they are simultaneously works of engineering, architecture, and landscape, which constitute "an artificial geography" (Hobbs, 1982).
The distinction between these different interpretations can be described through the "place" and "movement" functions of the street. The same words street and road, which are often used interchangeably, imply different meanings. Etymologically the word "street" derives from the Latin *sterne* (to pave) which denotes a surface that is part of the urban fabric, while the Anglo-Saxon root of "road", implies passages from one place to another, suggesting movement towards a destination (Rykwert, 1986). Thus, a street is often seen as a public space (Kostof, 1993), while a road is more of a functional artery (Maheshwari, 2020).
The "movement" and "place" functions of the street tend to conflict with each other, and it is normal that one imposes itself on the other (London Streetscape Guidance, 2022). This conflict over time has led roads to specialize, generally in favor of the car (Urry, 2004) and according to its urban, suburban speeds.
The gradual specialization of street space into functional transportation infrastructure has displaced its role as the 'housing of the collective' (Benjamin,1986) and architecture. The new dimension of street space has remarked the caesuras between parts of the city and disqualified all those mediating spaces (parterres and tree-lined strips, ditches and water collection channels, sidewalks, rotundas, parking lots, etc.). What new role can street space take on - its continuity, permanence or transformation with respect to the plots of routes, open space networks and infrastructure - in order to respond to the new environmental emergencies related to mobility, downsizing the auto-centric model?

3. Roads/streets, parking and related open spaces as device to experiment fragile territories' socio-ecological transition

Keeping as fixed points the interpretations on the meaning and role of the street derived from the rereading of some classics of literature (still relevant today), the research seeks to understand what new roles the street, car parks and related spaces can take on in the contemporary world, also in relation to the most recent phenomena affecting society and the environment, such as the pandemic (Gorrini et al., 2021) and extreme climatic events.

3.1 Street as complex ecology

An emerging aspect in recent years that roads, car parks and open spaces must take on is the mitigation of the effects of climate change. The road system not only contributes significantly to climate change but it's also the main victim of the consequences related to these changes (Carraro, 2017). Although the "environmental question" has been strongly posed since the 1960s[1], it is only in recent decades that the need to reduce emissions and the ecological footprint has become more evident through political and economic efforts. The green transition of road transport is the second most important investment areas of the National Recovery and Resilience Plan (PNRR)[2]. Despite in Italy there was a demographic decline between 2011 and 2020 (Istat, resident population, 2011-22) and a constant average family income (Bankitalia, 2011-18), the dominance of the car continues to remain relatively stable over time. Indeed, the motorization rate, in Italy among the highest in Europe, continues to grow (Aci statistical yearbook, 2011-20).

The emergence of new mobility models - such as shared services, electric and/or autonomous vehicles and progress in energy-related infrastructures - has still failed to call this stability into question. Among other things, the real ecological footprint of policies aimed at the development of electric vehicles is not yet clear. While representing a paradigm shift in terms of reducing C02 emissions, these models somehow reiterate the extraction of fossil materials (e.g. cobalt) to produce batteries (Carraro et al., 2023).

In recent years, especially in large cities, we are again witnessing a general demand (backed by political will) from citizens to re-appropriate street space for mixed use and mobility (Abdelfattah et al., 2022). A shared street, where there is no formal distinction between spaces dedicated to different transport modes, is never in a state of stability and inherently provides for acceptable levels of conflict.

The implementations of shared streets - starting with the pilot cases in Amsterdam and Vienna[3] - up to the many "tactical" experiments of global capitals - embody this conception of the street as a "space of dynamic relations" (Meta, 2014; Bocca, 2024), that derives from networks of interconnected activities, flows and phenomena.

Linking to the concept of "ecology" given by Banham for Los Angeles - to be understood not so much as simple protection of the environment but rather as a product of the interaction of geography, climate, economy, demography, technology and culture - the idea comes forward of the street as a complex ecology. Depending on the context and needs, it can take charge of the management of extreme stormwater, heat waves, air quality and extreme winds, biodiversity continuity, and waste.

Expanding these interpretations, the street also becomes a space of decompression, "urban emptiness" (Trancik, 1986; Secchi, 1986). Bernardo Secchi speaks of soil design also in terms of "thickness"[4], topography, while Gilles Clemènt provides the image of the "third landscape" (Clement, 2005) that arises at the edge of the roads as a corridor of biodiversity, and other landscape architects speak of "intermediate landscapes" (Desvigne, 2009), of ground depaving and reclamation, of green infrastructures.

On the one hand, we pursue the despecialization of the streets in the urban neighborhood networks (which are redesigned as woonerfs, with resilient floodable spaces, vegetation, spaces of shared mobility and continuity between services and neighborhoods) associated with strategies to strengthen public transport and

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1 Consider the thoughts of Ivan Ilich and the discussions on "political ecology" that inspired environmental movements in the years to come.

2 In Italy the energetic transition and the sustainable mobility is the first most important investment area of PNRR. t

3 A practical application of shared streets occurred in 1970 in Delft, where a group of residents transformed their neighborhood streets into "woonerven" - shared streets where the space for car movement was converted into shared public space. In Austria more recently, shared streets have become part of the "traffic code" through the introduction of the *Begegnungszone* or "encounter zone". Today, this type of space is experienced in many capitals around the globe and is codified in numerous street design manuals.

4 A large part of the streets' role is invisible in the contemporary city. The streets facilitate the space-time compression of urbanity by transporting people, goods, water, energy, waste and information in spaces that are all in all limited or underground (Graham & Marvin, 2001).

sharing mobility. On the other, greater specialization of broader road networks and metropolitan corridors, is required.

3.2 Street as equity space

But what happens if we move outside the street grids of dense metropolitan neighborhoods, if we change scale or context?

The experimentation of these sustainability measures on road space - shared roads, resilient public spaces, fifteen-minute cities, "tactical" roads and schools' streets - and the implementation of integrated mobility models[5], has taken place almost exclusively in large cities, which have a consolidated public transport network and greater investment power. These strategies have favored large cities, increasing the gap between metropolitan areas and other territories (Coppola et al., 2021). In recent years, a substantial part of European funds has been dedicated in Italy also to the most isolated areas, "the Strategy for Internal Areas" and mountains regions.

But, in the constellation of ordinary landscapes of small and medium-sized cities, in the territories of dispersion or informality or in those with low intensity of accessibility - which represent the majority in Italy (Lanzani, 2022) - the only possibility of mobility in reasonable times, compared to the daily needs of family, study and work, remains the private car. This phenomenon exacerbates an already known problem of disconnection and inequity in the accessibility (Ghigi & Nadini, 2022) potential of those marginal territories that can hardly be experienced with a sustainable and convenient way of moving.

According to Rudofsky (1969) the roads is not only a surface, part of an urban texture characterized by an extended area lined with buildings on either side but it's a volume (Rykwert, 1926), it is inseparable from its environment (Rudofsky, 1969), if in an urban context, a *continuum* with the ground floors of the buildings.

The same road, therefore, becomes a powerful connecting device between urban or environmental segments, starting from its distributive property. In ordinary urban contexts, often affected by scattered phenomena of abandonment, disuse, depopulation or regeneration opportunity, the street can be the bearer of vitality and greater widespread urban quality. Similarly, the road, within the non-urbanized open space, can take on the role of a biodiversity corridor and bridge between the fragmented parts. At different scales, the road is a device for balancing resources, from north to south and between large cities, intermediate and isolated territories.

3.3 Street as multiscale and multidisciplinary space

The third interpretation, transversal to the first two points, is related in fact to a necessary up and down scaling the transport and environmental scenarios, policies, master plan and projects from the global to the regional-local scale (or vice versa). It's the daily and incremental transformation of ordinary and small-scale public spaces that must contend with the global impacts of climate change and human activities. To implement integrated and systemic projects in specific places, it is necessary to understand the nature of their transversal relationships in a broader context.

The management of emergencies and disasters that have hit the Italian peninsula in the past has generated a series of political choices, for the restoration and recovery of the affected places, which are not very well adapted to the specificities of the territories, since they were taken, in most cases, very quickly. Also, the management of the approximately four hundred million euros allocated to the Italian territory in recent years[6],

[5] Which are based on the scale of mobility flows and urban dimensions.

[6] See Projects and reforms for the ecological transition MIT (2021).

coming both from the PNRR post pandemic emergency[7] and from previous agreements with Europe, is no less complex (Pasqui, 2021)[8].

Again, the timeframe for project implementation by public authorities is tight and the involved parties are seldom not equipped with trained skills. If it is partly understandable to act hastily and disconnected from the territories in emergency conditions[9], it is not so with respect to the myriad of ordinary maintenance, redevelopment and prevention activities carried out cyclically and extensively throughout our territory, but which remain chronically far from a perspective of medium and long-term planning, system planning, and monitoring.

In this perspective, the research wants to highlight also the role of the road as an artefact of an interscalar and multidisciplinary nature that could be able to bring into coherence with each other the multiplicity of sectoral tools that concern public open spaces, mobility and collective services spaces, and the disused, such as Urban Plans, Urban Traffic and Sustainable Mobility Plans, Green and Services Plans, and Implementation and Detailed Plans-the various projects and actions. The implementation of a multi-scalar and multi-disciplinary Atlas, which investigates the everyday life space of the road in relation to the environmental and socio-economic phenomena of some specific contexts and described in the following paragraphs, aims to orient policies and projects towards systemic knowledge and actions, making superordinate policies less generic, but also to systematise or define a set of good practices to achieve concrete and replicable results, also with a bottom-up approach (Richiedei & Pezzagno, 2022). The theme of the road again offers itself as an emblematic space for a significant and pervasive opportunity for systemic investigation.

4. Coastal territories as priority field of investigation

The relationship between infrastructure, climate change and coastal territory can be regarded as one of the most important architectural themes for our peninsula. In the transition zones between inland areas and the sea, the interaction between anthropic and climatic pressures leads to conflicts in the balance between economic development, securing and environmental sustainability (De Meulder, 2017).

Based on global, European and national scenarios, some main phenomena emerge that may induce relevant impacts for Mediterranean coastal areas (IPCC, 2022)[10]. In recent years, the European population living in coastal areas has more than doubled, and the same trend has occurred in Italy.

In Italy there are 644 coastal municipalities[11]. Almost 17 million people reside in these municipalities - just under 30% of the Italian population, to which the seasonal inhabitants should be added - which are distributed over about 43 thousand square km, just over 14% of the national territory (Mirto, 2022). Approximately one quarter of the surface area within the three hundred meters from the coastline, protected by Galasso Law, no. 431 of 1985[12], is urbanized. More than half of this territory is occupied by sprawl settlements (66%). The remaining part is made up as follows: dense settlements (21%), bathing facilities (7%), and infrastructure works (6%). The alteration of the shoreline stands at 8%: 62% with shore defensive structures, 38% with port and similar structures (Formato, 2019; Munafò, 2022).

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7 Which amount to 222.1 billion euros.

8 Structural Funds for development and cohesion 2021-27; REACT EU funds.

9 Perhaps, as Fabian and Bertin argue (Fabian & Bertin, 2021) the rhetoric of emergency has tended to hide the very character of the Italian territory, which by its very nature is fragile, unstable and, for the most part, very difficult to inhabit. It is necessary to assume the extreme fragility of our country as a given and ordinary condition.

10 The Mediterranean basin is defined as a climate change "hotspot", the most affected by rising temperatures in the world (Le Cozannet, 2022).

11 We refer to those municipalities that directly touch the shoreline (reference boundaries ISTAT 2022).

12 The Law introduced protection of landscape and environmental heritage. Through the editing of the "Piano Paesistico" each Italian Region imposes non-buildability constraints in some vulnerable and valuable landscapes (mountains, coasts and rivers, Ramsar zones). In our case, within 300 meters from the seashore. All the areas identified by Galasso are subject to state jurisdiction.

In 2021, almost 43% of the sandy coastline is occupied by bathing establishments, with considerable differences between regions. Moreover, when considering maritime state concessions[13], a 17% increase can be observed at national level over the last three years. Liguria and the Adriatic coast are much more congested, with 70% of sandy shores not freely accessible (Mirto, 2022).

Fragmentation has generated a progressive reduction of natural environments and an increase in their isolation. The result is a reduction in the resilience of habitats, which over time has affected the quality and value of the landscape (Nifosì, 2022), both natural and man-made[14].

Having dissipated the pre-existing territorial resources - landscape, environment, healthy air, which originally attracted inhabitants, vacationers, and tourists - and having consumed the "positional value", in many coastal settlements we are observing phases of decline and abandonment (Goula et al., 2012), even during the summer season. Residents and holidaymakers have preferred other or more attractive destinations. The result has been a gradual decrease in the number of visitors, the lack of care and maintenance of commons, and finally the diffused abandonment of public and private space (Nifosì & De Angelis, 2023). Roads, car parks, and services, losing their role, are underused. Much of the existing building stock, in excess compared to demand, has depreciated in value and now is not worth the taxes and maintenance costs necessary for its preservation (Formato, 2022). To these specific areas we turn our investigation and project attention.

4.1 Coastal Road Atlas. Methodology and first measurements

The methodology for the Atlas elaboration relates some coastal roads spatial dataset indicators with other demographic, socioeconomic and environmental indicators (Gargiulo et al., 2020). The quantitative aspects, represent in a series of national maps the aggregated indicators; the qualitative ones, through a bottom-up analysis on the case studies, looks closely at the morphologies of the roads, the land uses, the specific conditions. This methodology makes it possible to frame the national coastal system by aggregating phenomena that are often studied and viewed independently, to identify their interdependencies, and finally to assess the transformative and adaptive potential of the coastal everyday life infrastructures to contrast territorial fragility, abandonment and marginalisation phenomena.

The data collected and analysed from various national research institutes and public administrations are at the municipal scale and are represented in the Atlas, both at the national and at the local scale within certain focuses.[15] The following table shows the main sources used to produce the maps.

The roads, in linear geometry, were taken from the *Openstreetmaps* database, while the road surfaces come from the databases of some territorial authorities (municipalities, provinces and regions).

The density of coastal roads is expressed in km (graph) at the national scale and in sq.m. (surface area) at the local scale and analysed within some significant buffers: 300 m from the coast (Galasso Law, environmental protection constraint of the coastal strip), 1 km from the coast or within the municipal boundaries (Istat, 2022). For the definition of the "high coast" (which will have to mitigate the risk of landslides) and " lower coastline " (which will have to measure the sea level rise) on a national scale, the surface area below (or above) 20 metres asl was obtained from the INGV high-definition DTM (10 metres), re-processed as a contour line in vector format.

To elaborate some focuses among the "lower coastline" the density of coastal roads (expressed in surface) was cross-referenced with the scenario of ground level rise >1m and ground acclivity <5 degrees.

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13 The Ministry of Infrastructure and Sustainable Mobility, through the Maritime State Property Information System (S.I.D), has updated data on state property concessions after 3 years. The new data has been processed till May 2021.

14 In addition, the coastal zone planning framework in Italy is also characterized by the fragmentation of responsibilities (state, regional and local) for coastal zone management.

15 ISTAT borders were used for the socio-demographic analyses and the final representation, while OSM borders were used for the road density indexes elaboration.

A table with several indicators - and their sources - used in the mapping process is shown below (Tab.1).

	Year	Unit of measure	Source	Territorial extension
		Indicators		
Resident population	2005-2022	Inhabitants (Trend evaluation)	ISTAT	Municipalities
Average purchase and sale value	2005-2022	Euros per sqm (Trend evaluation)	OMI Database, Agenzia dell'Entrate	Municipalities, OMI zones
Share of inhabited dwellings	2019	% of dwellings	ISTAT	Municipalities
		Spatial datasets		
Terrain elevation	2022	Meters above sea level	DEM of Italy with a 10 meters cell size from INGV	Coastal areas
Roads	2023	Km	OpenStreetMap	Coastal areas
Landslide risk degree	2020-2021	Low-medium-high	ISPRA	Italy
Hydraulic hazard degree	2020	Low-medium-high	ISPRA	Italy

Tab.1 Sources used to produce maps

The following maps from the Atlas are an example of the application of the introduced methodology.
The first image (Fig.1a) relates the density of roads within the 1000 m buffer to the percentage of unoccupied houses in coastal municipalities. Territories that are more fragile than others in terms of underutilization (or capacity for re-use) are highlighted. On the other hand, the map on the right (Fig.1b) shows the change in the average real estate value trend in the littoral municipalities (the devaluation and revaluation of real estate assets), taken from the database of the Agenzia delle Entrate's real estate market observatory.
Coastal roads are interpreted as a potential space connecting segments and scattered artefacts affected by strong phenomena of disuse or seasonality, and therefore, as a potential for redevelopment of waterfronts through interventions aimed at the quality of public space and the environment.

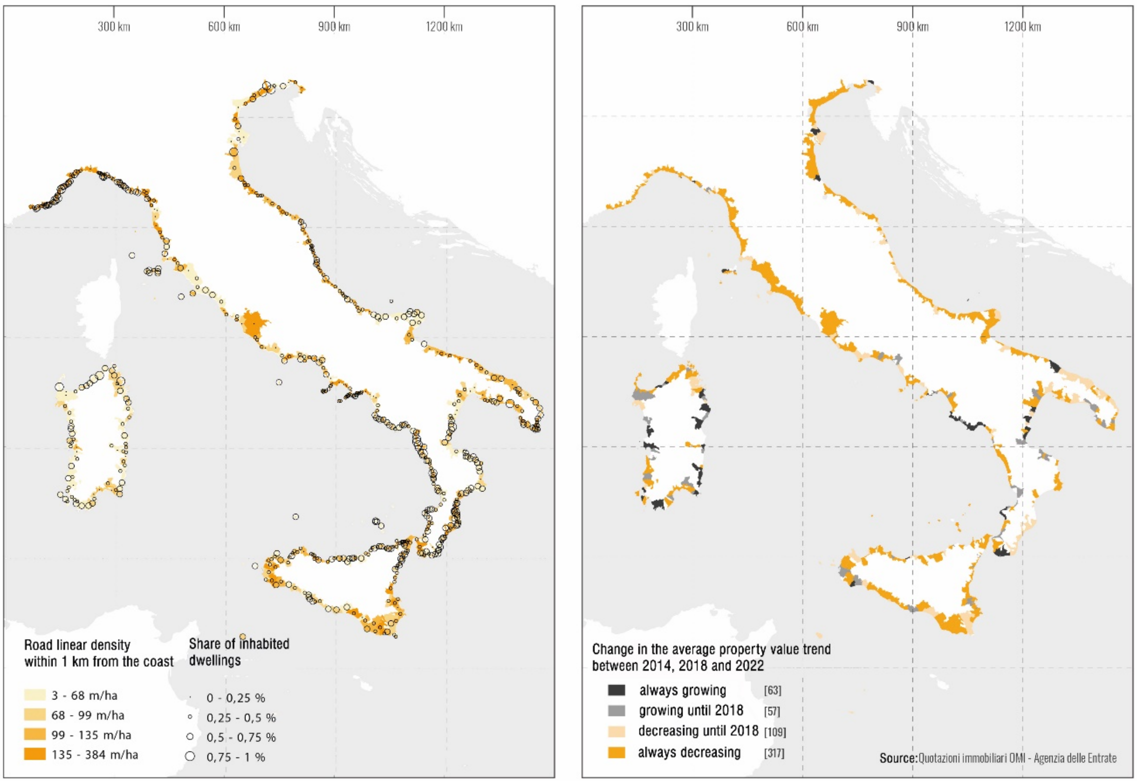

Fig.1 a) Unoccupied houses in coastal municipalities and coastal road density (left); b) Change in the average property value trend between 2014, 2018 and 2022 (right)

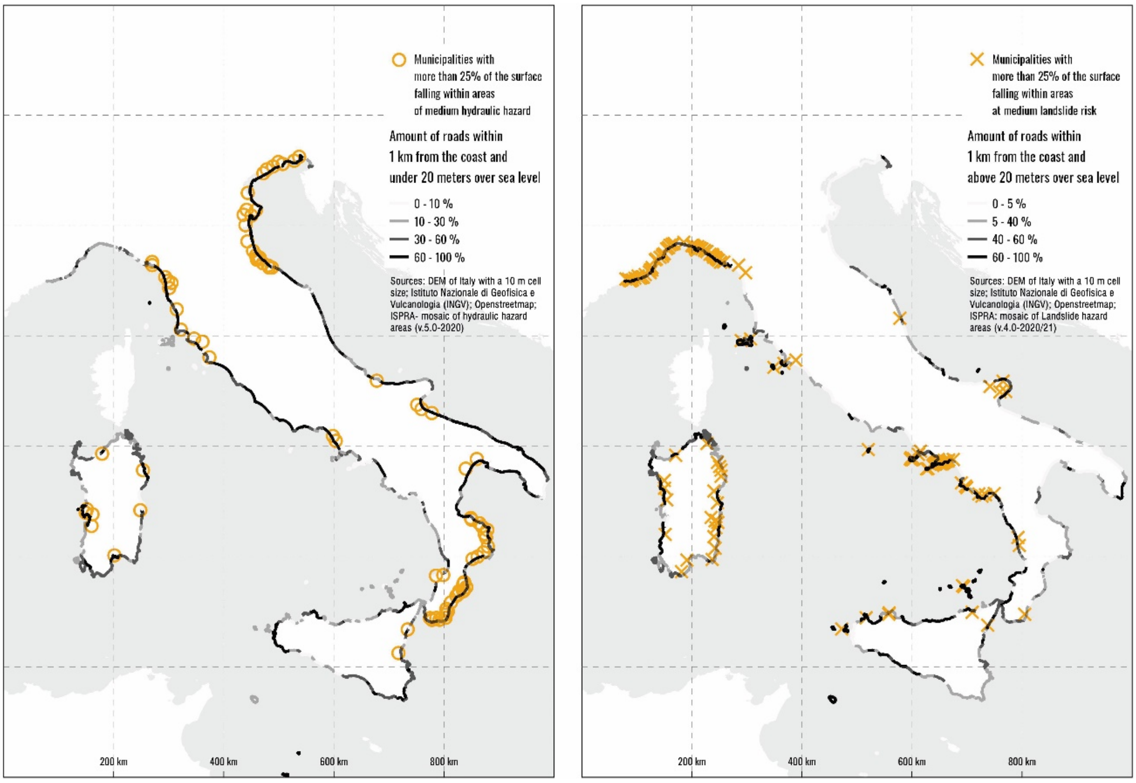

Fig.2 a) Roads density within 1 km from the coast, below 20 masl and hydraulic hazard; b) Roads density within 1 km from the coast above 20 masl and landslide hazard

Several criteria were used and superimposed to construct the next two maps (Fig.2a-2b). In the map on the left, the density of roads within 1 km from the coast and below 20 m above sea level is related to the hydraulic hazard (coastal municipalities that have more than ¼ of the area of the municipal territory classified by the PAI as at hydraulic risk). In the map on the right, the same spatial data are related to landslide risk (coastal municipalities that have more than ¼ of the surface area of the municipal territory classified by the PAI as at landslide risk).

4.2 Lazio region case study

As a relevant case for a more detailed exploration of a "lower coastline" we have chosen the region of Lazio, and in particular the territorial transect between the municipalities of Sabaudia and Sperlonga.

In Fig.3 the percentage of land use within 300 m and 1 km from the coast is estimated and depicted. The area of coastal roads (infrastructures in the legend) is placed in relation to the soil materials distinguished in densely urbanized areas, urbanized areas, green areas and urban equipment, agricultural areas, greenhouses, areas with wooded and shrub vegetation, riparian and coastal areas. A detailed land use analysis allows us to imagine a balance between impermeable and draining surfaces for water management risk mitigation.

The rise of the sea along the Italian coast is estimated by 2100 to be between 0.94 and 1.035 meters (conservative model) and between 1.31 meters and 1.45 meters (on a less conservative basis). The projections are given by the IPCC and ENEA. To these values we have to add the so-called storm surge, i.e. the coexistence of low pressure, waves and wind, which varies from area to area (Bondesan et al., 1995), which in particular conditions causes a rise in sea level with respect to the coastline of about 1 meter.

In the Fig.4, the road area (expressed in square meters) within 300 meters from the coast with ground acclivity < 5°, is superimposed on three different sea level rise scenarios (1,2,3 meters) and on the PAI medium hydrogeological risk band. Within this transect, in addition to the area of exposed road infrastructure, the resident population at risk is also estimated.

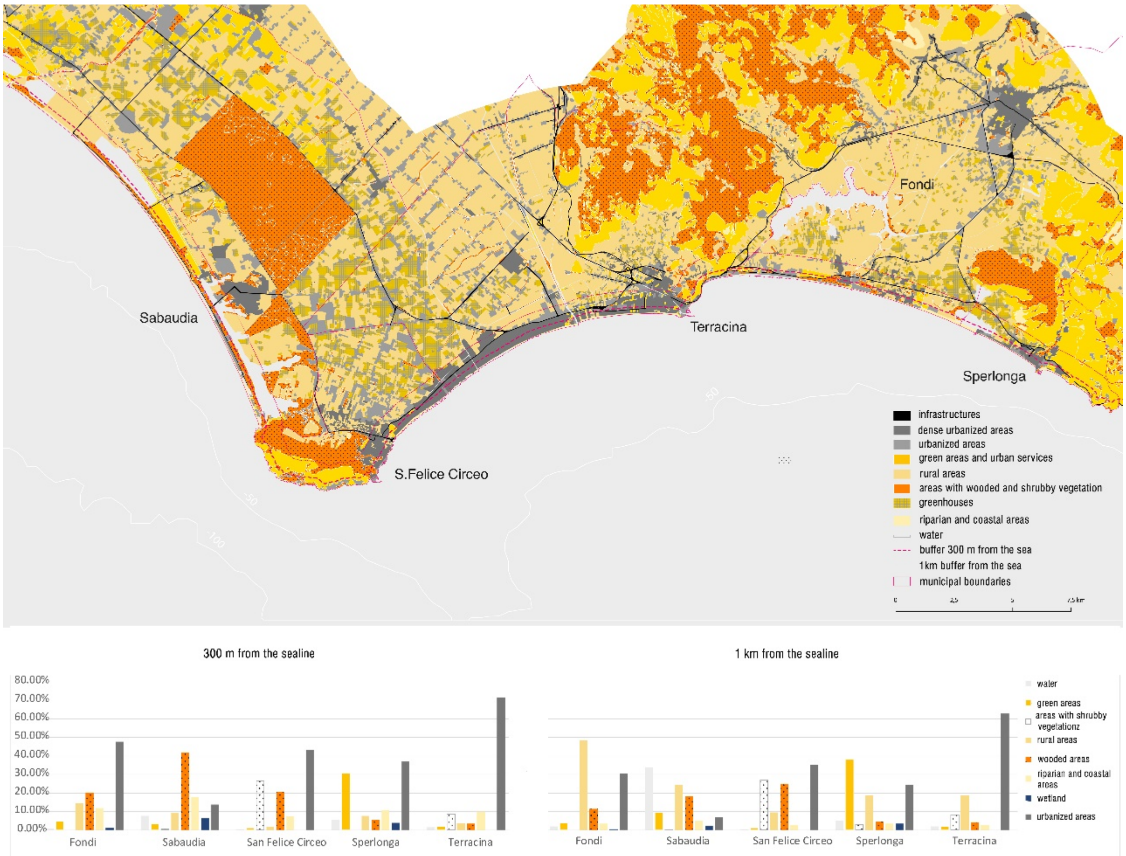

Fig.3 Percentage of land use within 300 m and 1 km from the coast between Sabaudia and Sperlonga

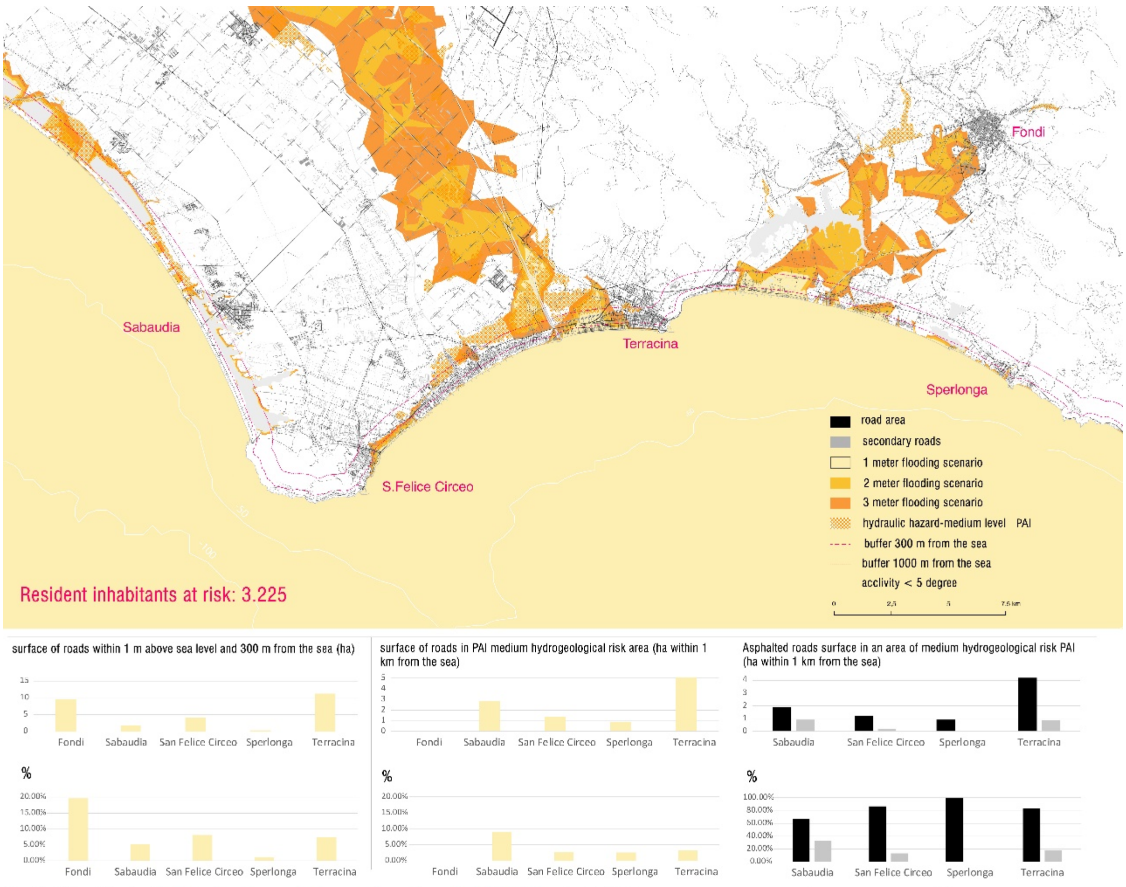

Fig.4 Circeo peninsula Focus. Road area within the medium hydraulic hazard and sea level rise scenarios related to the inhabitants (3,225 inh.)

In the composite image we see at the top the analysis of the entire transect, and at the bottom a focus on Terracina. The central table summarizes: the quantities (in hectares and percentage) of roads at risk of flooding, within the 1 m sea level rise scenario, falling within 300 meters and 1 km from the coast; the quantity of roads falling within the PAI medium risk band and within 1 km from the coast. Finally, paved roads (urban, provincial and state) and minor roads (dirt roads and paths) falling within 1 km from the coast are distinguished and quantified. Here too, it is interesting to measure the degree of waterproofing of road soils to possibly devise strategies for de-paving or protecting white roads, replacing the road surface with more draining materials, and introducing rain garden systems starting from the redesign of the road section.

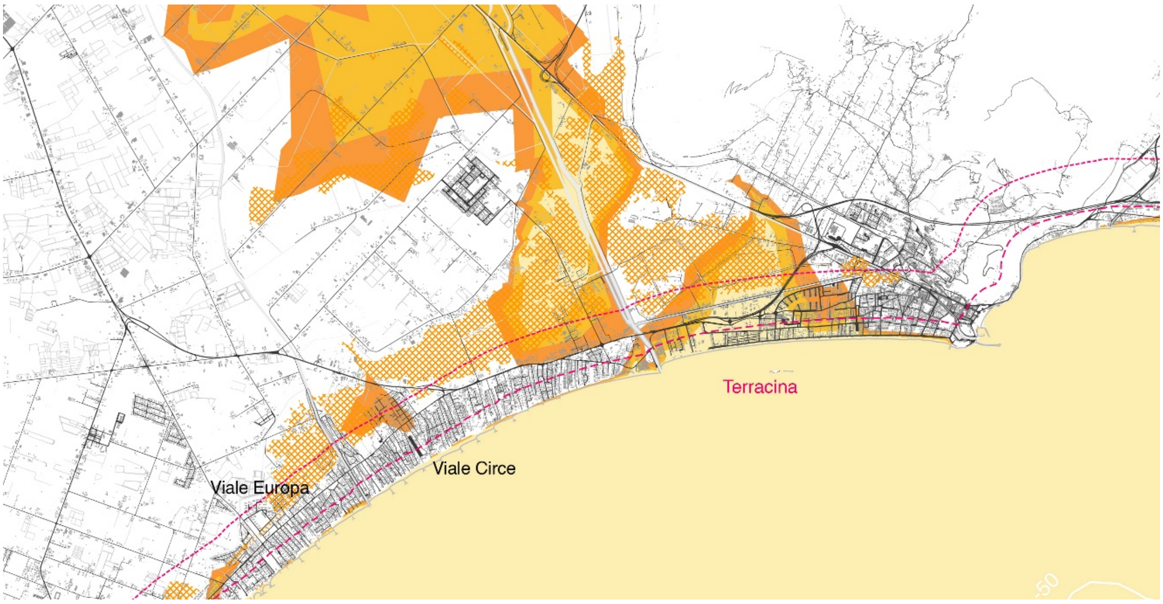

Fig.5 Terracina focus (2,636 inh.)

Fig.6 Morphological readings and bottom-up mapping of Terracina's coastal roads

5. Conclusion

The study analyses the effects of the ongoing socioeconomic and climatic changes in Italian coastal territories through the lens of road space and aims to implement a multi-scalar atlas aimed to make the multiplicity of sectoral tools and projects working on everyday public spaces coherent with each other, in response to ongoing changes. The concentration of population and economic activities along the coast has been based, and is still based, on infrastructures that depend mainly on road transport (Rocchi et al., 2023). Lines, grids, combs of coastal roads have rigidified the coastline, reducing its natural thickness that governed its hydraulic regulation. Damage caused by climate change is expected to increase significantly over the century. In particular, the intensification of flooding for low-lying coasts and landslides for high coasts, will cause an increase in the number of people and commons exposed to risk. By integrating social-climate resilience into the planning (Burden, 2013; Carra, 2022), design and ordinary maintenance practice of coastal roads, risks for infrastructure and communities can be reduced and long-term adaptation processes can be fostered. The measures that can be pursued are of different types (Al, 2018) and find their way not only into road areas but also into the appurtenant spaces that are available or will be made available. Actions can be taken, for example, through:

- a planned setback;
- a planned selective demolitions actions associated with forms of compensation/equalization for private actors involved;
- the reclassification of some coastal roads, rethinking them with pedestrian and bicycle priority (Tira, 2005), building new relationships between the coast, the network of services and underused assets;
- the implementation of existing ecosystems through the conservation or restoration of coastal habitats and biodiversity, strengthening the natural framework of the remaining coastal territory;
- dynamic coastal management that may include the restoration or creation of natural buffer zones (beach nourishment, dune stabilization, wetlands, shrublands or wooded areas that can absorb wave energy and provide natural protection against storm surges, reducing the vulnerability of coastal roads;
- the introduction of green infrastructure within coastal roads for water and temperature management (rain gardens, permeable pavements and biofiltration systems). Starting from the more detailed observations of the case studies, the experimentation of these measures on the coastal roads in the most vulnerable parts of the territory will proceed towards two declinations: 1) measures for the highways (SP, SS) where it will be urgent to rethink the problematic relationship between living spaces, services and crossing car traffic; 2) the network of secondary urban roads, which can be reconsidered as waterfronts, with limited traffic, greener and bluer.

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Evaluating active mobility: enhancing the framework for social sustainability

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Abstract
Active mobility plays a crucial role in reducing traffic congestion, improving air quality, promoting well-being, good health, and fostering social equality, all of which align with the concept of social sustainability within the Sustainable Development Goals (SDGs). However, assessing the impact of active mobility on social sustainability remains challenging due to the lack of clear identification of the specific SDGs influenced by it. This review analyses how previous articles quantify active mobility, its antecedents, and impacts. Additionally, it aims to find if any impacts can contribute to defining Social Sustainability. A Rapid Evident Assessment method was employed in this research in two databases: PsycINFO and Scopus. Out of the first pool of 61 papers, 19 articles were selected. The findings provide a comprehensive framework of the variables that influence active mobility and those influenced by it. Active mobility predominantly contributes to addressing the 11th, 10th and 3rd SDGs. Furthermore, the social sustainability quantification can benefit from assessing active mobility impacts. This work also identifies knowledge gaps, offering valuable guidance for future research in the field.

Keywords
Urban planning; Sustainability; Behavioural change; Review.

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1. Introduction

Active Mobility (AM) is a regular physical activity undertaken as a means of transport. It includes walking, cycling, pedal-assisted e-bikes, kick-scooters, skateboards, and other vehicles which require physical effort to get moving, while it does not include physical activities that are undertaken for recreation purposes (EIT Urban Mobility, 2020). There are both individual and public health benefits of active mobility, primarily through the direct impacts of physical activity, but also indirectly through reduced air pollution and noise pollution if AM modes increase due to a shift from non-active modes (e.g., Carra et al., 2023; D'Amico, 2023; Gargiulo & Sgambati, 2022; Tira, 2018). As well as the considerable health benefits, active mobility modes provide benefits in terms of reducing the amount of space used (compared to cars), freeing up space in public transport, reducing CO_2 emissions, and reducing social inequality (Carpentieri et al., 2023; EIT Urban Mobility, 2020; Hwang & Guhathakurta, 2023). Despite the sparse use of the term AM in recent examples of international debate (Pezzagno & Richiedei, 2022), AM can contribute to more sustainable development, in consideration of its definition as "development that meets the needs of the present without compromising the needs of future generations to meet their own needs" (WCED, 1987).

The concept of sustainable development was further systematised into the 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015. The Agenda proposes 17 sustainable development goals (SDGs) with 169 targets, whose achievement is quantified by 248 indicators. Considering what was reported above, AM can contribute to reaching the 11th (sustainable cities and communities), 3rd (good health and well-being) and 10th (reduce inequality) SDGs.

The SDGs aim to intervene in three dimensions of sustainable development: the social, economic and environmental. Although these pillars have been deeply investigated, Social Sustainability (SS) remains a fuzzy concept, with no blueprint conceptualisation in policy documents or academic papers (Foladori, 2005).

Social Sustainability has received many definitions, which standalone or interact with environmental sustainability. One of them says that it is "the set of policies, rules and principles laid down in the EU legal order, that aim to reinforce the social dimension of the EU as a long-term solution, ring-fencing it from any relapse into a position of hierarchical subordination to the markets, so that Social Europe can unequivocally be perceived an equal counterpart to the economic constitution" (Alexandris Polomarkakis, 2019). Additionally, it was suggested that the key elements of SS are social progress, improving welfare and living conditions, social cohesion, social policy, urban development, company and organisation performance (McGuine et al., 2020), work conditions, education and social equality (Giovannini, 2018). These elements can fall into the SDGs 11th, 3rd, 4th (quality education), 5th (gender equality), 10th and 8th (decent work and economic growth).

Based on these premises, some of the Social Sustainability objectives could be achieved, or partially fulfilled, by investing in shifting from combustion engine-based transportation to Active Mobility. Thus, this work aims to investigate how the measures of AM can contribute to defining the different aspects of SS.

Therefore, this article will answer to the following research questions: (i) Which variables intervene in enhancing or decreasing AM behaviours, and how were they measured? (ii) How were AM behaviours measured? (iii) Are there any AM impacts that can contribute to reaching the SDGs?

To achieve this goal, a systematic review, performed by the Rapid Evidence Assessment method (Barends et al., 2017), is executed.

This contribution discusses how the active mobility impacts, which were relevant for SDGs, were connected to social sustainability, as well as if it is possible to adopt the AM's affecting variables as parameters for social sustainability assessment.

Moreover, the European community policies encourage providing free access to scientific material. Considering that, it becomes crucial to investigate whether the articles selected for review were open-access and aligned with the primary focus of the publishing journal.

2. Method

A Rapid Evidence Assessment (REA) provides a balanced assessment of what is known (and not known) in the scientific literature about an intervention, problem or practical issue using a systematic methodology to search and critically appraise empirical studies. However, to be 'rapid', an REA makes concessions about the breadth, depth and comprehensiveness of the search. Due to these limitations, an REA is more prone to selection bias than a systematic review (Barends et al., 2017).

2.1 Search strategy and study selection

PsycInfo and Scopus databases were adopted to identify the studies. The search strategy uses the term "active mobility" in keyword: KEY ("active mobility"), performed in January 2023. The following generic search filters were applied to all databases during the search: Peer-reviewed (excluded reviews), Published from 2021 to 2023, written in English.

Articles were included if they met the following criteria: quantitative or empirical studies; studies in which the effect of variables (moderators and/or mediators) on AM and/or its outcome were measured; studies that report variables correlation with AM; research context belongs to Urban Planning or Behavioural Science.

Articles were excluded if they met at least one of the following criteria: method entirely based on simulation.

Two authors independently analysed the records of the searches. As reported in Fig.1, out of the 61 articles generated by the preliminary search strategy, 7 were excluded because repetitions, 1 (de Melo et al., 2022) was not possible for retrieving, 19 were excluded by reading the title and abstract as they were irrelevant to the study criteria. After reading the full text, 15 more studies were excluded.

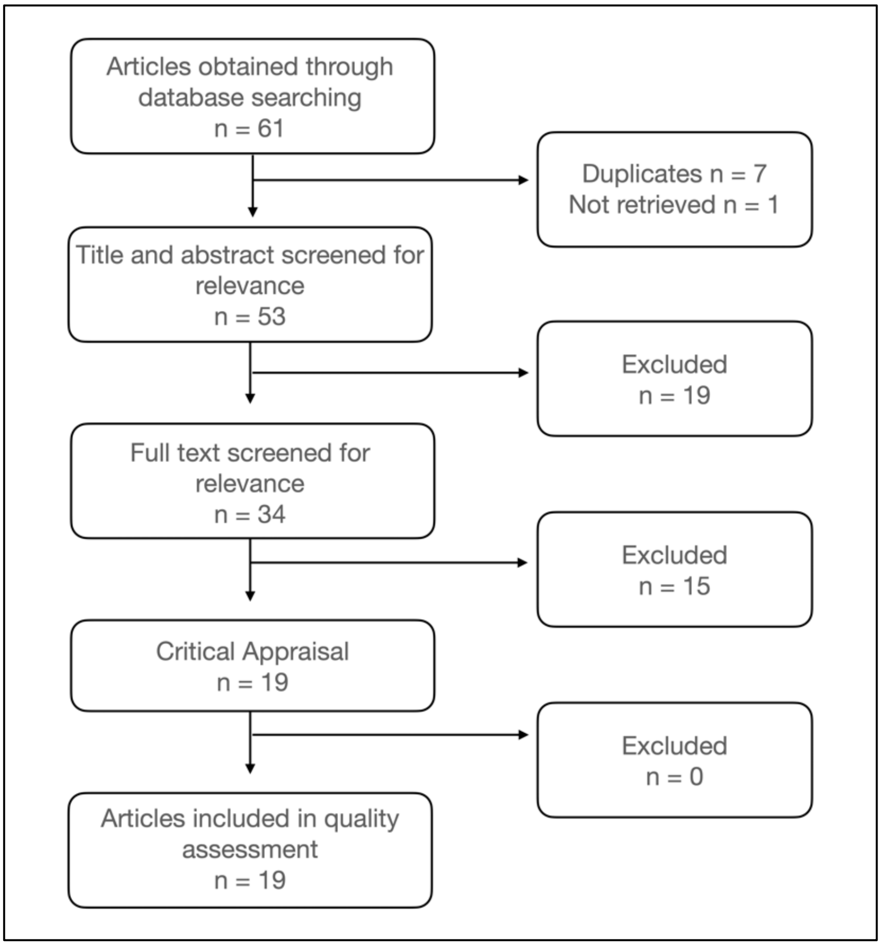

Fig.1 Study selection flowchart

2.2 Assessment of the Studies' Quality

Because of the aims of this review, the main selected articles are traced to cause-and-effect claims. In this case, a study has high methodological appropriateness when it fulfils the three conditions required for causal inference: co-variation, time-order relationship, and elimination of plausible alternative causes. Therefore, studies that use a control group, random assignment and a before-and-after measurement are regarded as the 'gold standard' for effect studies. A six-level classification of appropriateness was used (Tab.1) to determine the methodological appropriateness of effect studies and impact evaluations; it was based on the classification system of Shadish et al. (2002) and Petticrew and Roberts (2008).

Design	Level
Systematic review or meta-analysis of randomized controlled studies	AA
Systematic review or meta-analysis of non-randomized controlled and/or before-after studies	A
Randomized controlled study	
Systematic review or meta-analysis of controlled studies without a pretest or uncontrolled study with a pretest	B
Non-randomized controlled before-after study	
Interrupted time series	
Systematic review or meta-analysis of cross-sectional studies	C
Controlled study without a pretest or uncontrolled study with a pretest	
Cross-sectional study (survey)	D
Case studies, case reports, traditional literature reviews, theoretical papers	E

Tab.1 Classification of studies' methodology appropriateness

2.3 Data extraction, synthesis and analysis

The following data were extracted for each of the included studies: sector (Urban Planning, Medicine Science or Behavioural Science) and population (the object of the investigation), study design (reported according to Tab.1) and sample size, variables that affect AM and their assessment tools, and the study quality level (according to Tab.1). Finally, the relevance of the SDGs is assessed by confronting the topics faced by the articles and the goals as well as the target reported in the SDGs framework of the 2030 Agenda for Sustainable Devolvement (United Nations, 2023).

The results are reported in Tab.2. The Active Mobility definition, AM assessment tool, variable affected by AM and their assessment tool, and the main articles' results are reported in Rainieri et al. (2024).

Data were independently abstracted by two authors, and any discordance was resolved by consensus. Because the studies were different in terms of design, setting, interventions, and outcome measures, a narrative synthesis was planned (Popay et al., 2006).

Reference	Sector & Population	Design & Sample size	Variables affecting AM & Measures	Level	SDG
Giuffrida et al. (2023)	Urban Planning / Dublin city	Case study / None	Accessibility (Hansen measure; PTAL method)	E	9 – 10 – 11
Möllers et al. (2022)	Urban Planning / Germany	Before-after study / 10 cities	Government intervention Weekly days and hours	B	3 – 16
Hasselder et al. (2022)	Behavioural Science/ older adults, Germany (rural	Field study Survey / N = 2137	Perceived distance; Self-rated health;	D	3 – 10 – 11

Reference	Sector & Population	Design & Sample size	Variables affecting AM & Measures	Level	SDG
	communities or small and medium-sized towns)		Environment Walkability Scale (NEWS)		
Hollenbeck et al. (2022)	Behavioural Science / general population, Stuttgart	Within-subject study / N = 46	-	B	3 – 11 – 15
Sundfør & Fyhri (2022)	Behavioural Science / general population, Oslo	Between-subject study / trial: N = 382, control: N = 665, buyer: N = 214	e-bike subvention program	B	10
Lee (2022)	Behavioural Science / General population, Seoul	Survey / N = 20,000	Pedestrian satisfaction	D	10 – 11
Doi et al. (2022)	Medicine Science / older adults, Japan	Survey / N = 4432	Depressive symptoms; Frailty; Cognitive impairment; Disability	D	3
van Hoef et al. (2022)	Behavioural Science / adolescents, Switzerland	Between-subject / trial: N = 48, control: N = 29).	Bicycle promotion program; Cycling skill; Cycling habits; Distance	B	4 – 13
Kurita et al. (2022)	Medical Science / Older adults, Japanese	Meta-analysis / N = 21644	-	A	3
Pisoni et al. (2022)	Urban Planning / European general population	Database analysis /N = 26500	Trip distance, Country, Vehicle ownership, Gender, Type of employment (EU Travel Survey (2018))	D	8 – 11
Brüchert et al. (2022)	Urban Planning / older adults, Germany	Cross-sectional study / N = 1836	Urban design features	D	11
Carboni et al. (2022)	Urban Planning / general population, Valencia, Turin	Cross-sectional study / N = 865	Urban features	D	10 – 11
Said et al. (2022)	Behavioural Science / general population, USA	Cross-sectional study / N = 826	Self-identity; Place Identity; Personal norm Social identity; Work-schedule flexibility; Owning-vehicles; Pedestrian infrastructure; Multimodality (diary)	D	
Mehriar et al. (2021)	Urban Planning / general population, Pakistan	Cross-sectional study / N = 861	Street-length density	D	4 – 8 – 11
Scorrano & Danielis (2021)	Behavioural Science / general population, Trieste (IT)	Cross-sectional study / N = 315	Concern for the global and local environment; Attitude toward physical exercise; Risk aversion towards Covid-19; Theoretical change in policy	D	11
Giansoldati et al. (2021)	Urban Planning / general population (IT)	Cross-sectional study (Survey and Predictive model) / N = 185	Travel time and cost	D	11
Brand et al. (2021)	Urban Planning / general population, EU	Cross-sectional study / N = 3836	-	D	9 – 10 – 11
Fonseca et al. (2021)	Urban Planning / Bologna IT, Porto PT	Cross-sectional study / N = 3836	Travel distance and time; Sidewalk conditions	D	8 – 11
Arranz-López et al. (2021)	Urban Planning / general population, Spain	Cross-sectional study / N = 267	-	D	11

Tab.2 Data extracted

3. Results

The results are presented in the following paragraphs about Active Mobility definition (3.1), Variables affecting Active Mobility (3.2), Active Mobility measures (3.3) and Variables affected by Active Mobility (3.4). At the end of this last paragraph, a Figure summarize all variables.

3.1 Active Mobility definition

Active Mobility appear as a construct poorly described (four articles did not even provide a definition) or with a shared acknowledgement.

Two articles considered just walking as their AM study object, and one article considers public transport as well (Fonseca et al., 2021). In addition to walking, seven articles examine cycling, while two studies included bike-sharing (Said et al., 2022) and e-biking (Brand et al., 2021). Precisely, even if Giuffrida et al. (2023) employed walking and biking to define AM, their study's object was the bike-sharing system. It is worth mentioning that the European Directorate-General for Mobility and Transport defines Active Mobility as "namely walking and cycling" (European Commission).

Moreover, Scorrano and Danielis (2021) encompassed riding personal mobility devices (scooter, rollerblade, skateboard and wheelchair) to AM, while other authors (Carboni et al., 2022; Giansoldati et al., 2021) find a common and general perspective, defining Active Mobility as "all the modes of transport based on human-powered for propulsion".

Besides, it is worth noting that all the articles addressed the concept coherently with the definition provided by EIT Urban Mobility (2020). Thus, Active Mobility is considered by all as a physical activity not undertaken for recreational purposes.

3.2 Variables affecting Active Mobility

Regarding the behavioural science dimensions, Said et al. (2022) reported that the perceived quality of the built environment affects walking propensity but not cycling. It was observed that self-identity (i.e., the concept of seeing AM as a reflection of oneself and embodied ideals) is significant for all the transportation modes, implying that utilising active travel modes is, in part, a consequence of identity-behaviour congruence. Moreover, individual-environment congruence (place identity) is fundamental to the adoption of habitual cycling behaviours. Scorrano and Danielis (2021) stated that respondents who are more concerned about the global environment derive a higher utility from cycling.

It was found that the satisfaction level towards the pedestrian environment during day and night time increases the satisfaction with the neighbourhood (Lee, 2022).

Considering the urban planning field, accessibility is a necessary condition for Active Mobility (Giuffrida et al., 2023). The authors measured the accessibility of the bike-sharing system with a composite index for both active (Hansen-like measure) and passive access (adapting the Public Transport Access Level method).

Within a 20-minute walking distance from the participants' homes, the strongest associations with walking for transport were found for small stores, pharmacies, and bakeries. At the same time, the bus stop showed the weakest associations (Hasselder et al., 2022).

Mehriar et al. (2021) stated that the frequency of AM behaviours around home increases when the amount of street-length density (connectivity) is more than 137 m/m^2 (for commuting) and 10.33 m/m2 (for non-commuting), while the opposite effect was observed around workplaces, where lower street-length density was connected to higher AM behaviours.

Fonseca et al. (2021) showed that travel distance, travel time and sidewalk conditions were the main barriers to utilitarian walking. Giansoldati et al. (2021) confirm that travel time and cost play a relevant role in determining transport choice. They found that being commuters lowers the disutility from the time spent

cycling or walking. The authors calculated that the active modes ranges were, on average, equal to 1.3 Km for walking and 2.1 Km for cycling, while the maximum distance for walking was 3 Km and 4 km for cycling.
Brüchert et al. (2022) reported that both AM and car-oriented users rated urban features (such as road safety, surface quality, good lighting, and walking space) as important, but with different magnitude, especially for speed reduction. Carboni et al. (2022) stated that cyclists are somewhat affected by safety issues and concerned about sharing space with other vehicles.
About the Socio-demographics, it seems clear that a healthier and younger population is more likely to exhibit AM behaviours. The fact that drinking habits are associated with AM may suggest that people are more willing to use AM for pleasure reasons.

3.3 Active Mobility measures

Literature adopted several assessment tools. Only Pisoni et al. (2022) used an indirect data source by deriving information from the EU travel survey (edition of 2018 with 26,500 responses) that allowed the association of socio-economic and demographic attributes with user choices concerning transport and mobility. Data earned concerned: availability of cars and public transport services, daily mobility in terms of purposes and modes used, number of trips, trip frequency, durations, distances, intermodality (e.g., connections between rail and air transport), main problems experienced, long-distance trips in the last 12 months.
Mollers et al. (2022) used counting stations (provided by Hystreet for pedestrian counts by EcoCounter for cyclists). Bollenbach et al. (2022) adopted a walking-triggered e-diary, which was accomplished using an interface between a smartphone (for electronic diaries, GPS- and transmission tower location tracking) and a hip-worn accelerometer. Similarly, Sundfør et al. (2022) used app-based questionnaires, which had a one-day travel diary section, starting with an explanation of the procedure for how to define a trip, travel mode, trip purpose (14 categories from the Norwegian National Travel Survey), distance and time spent. Additionally, the app collected position and speed through GPS and accelerometer. Notably, the authors distinguished between biking for transport and exercise.
Said et al. (2022) assessed participants' travel habits, asking them to complete a "weekly travel diary", which collected the number of trips, travel modes and trip purposes.
Questionnaires represented the main method. Hesselder et al. (2022) measure if the participants walk for transport by a single item (Do you walk for transport with a duration of at least 5 minutes?). Arranz-López et al. (2021) asked for the respondents' actual walking time to daily and non-daily retail destinations (real accessibility) as well as their walking time-willingness (potential accessibility). Doi et al. (2022) and Kurita et al. (2022) developed and applied the Active Mobility Index (AMI) questionnaire to assess physical and social activities.
Summarising the content of the questionnaires, typical items inquired about the mode choice, or a combination of modes (Bruchert et al., 2022; Carboni et al., 2022), in relation to weather conditions (Scorrano & Danielis, 2021; Van Hoef et al., 2022) and if the trip was a communing one or not (Mehriar et al., 2021) or the purpose of the trip in general (Fonseca et al., 2021). Additional items could ask for trip characteristics, such as travel time and cost (Giansoldati et al., 2021), vehicle ownership, and public transport accessibility (Brand et al., 2021).

3.4 Variables affected by Active Mobility

Brand et al. (2021) confirmed the mediating role of trip purpose on CO_2 and highlighted how travel to work or education produced the largest share of emissions; there were also considerable contributions from social and recreational trips.
Giuffrida et al. (2023) reported that the higher the accessibility of the bike-sharing system, the higher the transport equity and social inclusion. Therefore, the authors employed the concept of "horizontal equity", i.e.,

the spatial distribution of bike-sharing stations. To perform this analysis, they used the Gini index, defined mathematically as the ratio of the area that lies between the line of perfect equality (bisector of the first quadrant of the Cartesian plane) and the Lorenz curve. In the case of this article, it was considered the distribution of the accessibility measure among the zonation of the city under analysis.

Pisoni et al. (2022) calculated that shifting 10% of car-based transportation to AM can save more than 10 billion EUR per year. The external cost was assessed in terms of Well-to-Tank emissions, noise, habitat, congestion, climate, air pollution, and accidents.

Kurita et al. (2022) reported how a larger living space with physical activity is protectively associated with sarcopenia and its indices.

Bollenbach et al. (2022) found that those who were walking in a greener environment were more calm or more relaxed. The affective state can be described by: calmness and energetic arousal, both predicted by social interaction intensities while walking in green areas.

Said et al. (2022) reported that walking contributes to a good mental map of the neighbourhood, while biking is related to multimodality, openness to learning, and variety seeking, suggesting it is more connected to being open to change and learning new skills.

As mentioned, Fig.2 offers a comprehensive representation of the relation between the variables.

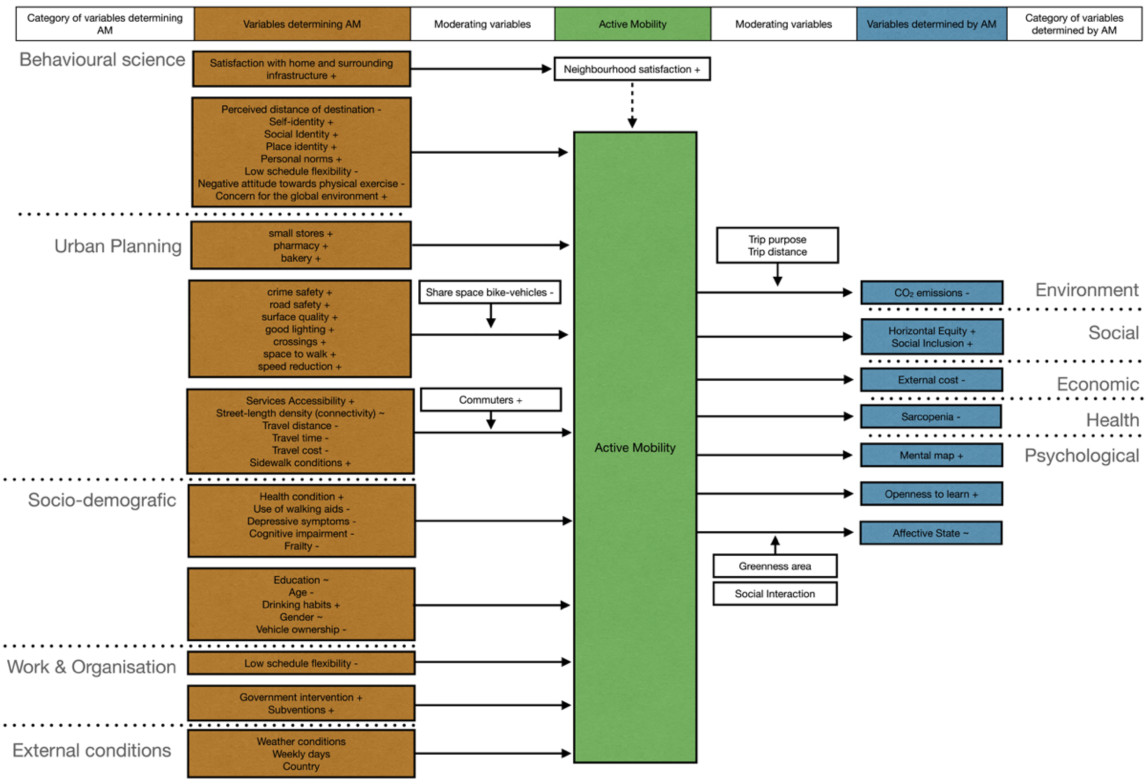

Fig.2 Comprehensive framework of Active Mobility. All the variables are characterised by a sign: + when it increases AM, - when it decreases AM, ~ when the relation is ambiguous. Note that "neighbourhood satisfaction" has a potential, but not demonstrated, influence on Active Mobility

3.5 Which SDGs were mainly addressed by Active Mobility?

The analysis showed that the 11th SDG (Make cities and human settlements inclusive, safe, resilient, and sustainable) was addressed fourteen times. The 11.2 target is the one main concern for AM. Specifically, the concept of transport accessibility (pedestrian path and bike sharing), thus the location of the resources and

the spatial range of transports, emerges as a strategy for reaching inclusiveness while offering solutions for sustainable transportation (Arranz-López et al., 2021; Giuffrida et al., 2023).
Another study works in this direction (Scorrano et al., 2021), claiming that those who show AM behaviours were more concerned about the global environment, somehow addressing the target 11.3.2.
The 10th SDG (Reduce inequality within and among countries) was addressed six times. Accordingly, a subvention programme intended to support active transporters' purchases (e.g. bike and e-bike) can reduce inequality by offering the opportunity to obtain functional, new, well-designed transports to everybody.
Furthermore, to promote active mobility, governments need to invest in infrastructure that enables actual and perceived safety (Carboni et al., 2022); in this sense, the promotion of active mobility would achieve a higher state of well-being. Thus, the provision of a safe environment that incentivises the use of active mobility means would bring the extremes of society closer together.
The 3rd SDG (Ensure healthy lives and promote well-being for all at all ages) was addressed four times. Summering the results, it was found that good health conditions and low frailty were negatively related to AM choices (Hesselder et al., 2022), which in turn reduces Sarcopenia, an age-related loss of skeletal muscle mass and strength (Kurita et al., 2022).
The 8th SDG (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all) was found relevant three times. The emissions analysis for trip purposes highlighted the relative importance of the systematic trip from home to work/education place (Brand et al., 2021). This finding suggests that the work-organisations have the potential to foster the adoption of AM choices.
Regarding the 4th SDG (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), addressed two times, it is worth saying that the Education concept remains a fuzzy factor. While some authors found that AM was connected to a higher educational level (Doi et al., 2022), others reported it was more probable in low education conditions (Pisoni et al., 2022). Interestingly, biking was related to openness to learning, suggesting it is more connected to being open to change and learning new skills (Said et al., 2022). Moreover, Lee (2022) found no correlation between the educational environment and neighbourhood satisfaction.
A particular mention is due to the cycling promotion programme and bicycle training for adolescents in high school (Van Hoef et al., 2022), which demonstrate how working towards AM can contribute to fulfilling the indicator 13.3.1 (citizenship education for sustainable development mainstreamed in national education policies and student assessment).
For a more comprehensive description, see Rainieri, Carra, Richiedei and Pezzagno (2024).

4. Discussion

In this section, the results are commented on, as well as the connections between Active Mobility and Social Sustainability, and the scientific community’s commitment towards the topic.

4.1 Active Mobility

In light of the elements raised by the considered articles, Active Mobility can receive the following comprehensive definition: physical activities undertaken for transportation, not for recreational purposes, which encompass walking, cycling, e-bike, bike-sharing, public transport, and all the modes of transport based on human-powered for propulsion. To be precise, it is reasonable to acknowledge that every journey inherently includes walking. As highlighted by Busi (2011), all the odd-numbered connections within the sequence of transportation modes manifest as pedestrian movement.
The assessment of Active Mobility behaviours considered the collection of trajectories and feedback from mobile app data, and it appears promising. However, the data are rough and prone to misunderstandings, such as when distinguishing walking from biking. It was reported that 75% of professionals stated they were

only partly able to solve their tasks using the data available to them. Additionally, 60% of the respondents were able to quantify the modal share for cycling for their zone, while only 51% were able to state the main cyclists' trip purpose. Nonetheless, having these kinds of data could be beneficial for both the public and private sectors that are dealing with active mobility (Werner et al., 2021).

Moreover, the assessment of variables affecting AM could be beneficial for a better organisation of the city and its policies (e.g., Carra et al., 2022). Considering the impacts, active mobility behaviours yield beneficial outcomes in the environmental, social, economic, health, and psychological realms.

Considering the path length perception, the e-bike has the potential to change people’s attitude towards AM, offering a more comfortable and fast mode of transportation, able to change people's mental city map. However, the lack of (perceived) road safety remains currently the main barrier to cycling (Maas & Attard, 2022). Generally, all the research outcomes highlighted that cycling presents multitude of challenges for urban planners. These primarily revolve around effectively offering infrastructure for organising trips and providing supportive equipment that can mitigate concerns related to weather conditions.

However, it was stated that increasing the bike infrastructure (cycle paths) would not translate into an increase in active mobility since the bike would substitute some trips currently made by foot (Scorrano et al., 2021). Taking this statement as a challenge, an integrated transportation system (such as general subscription for bike-sharing, public transport, and parking) could change this trend since it offers high flexibility of choice that can vary according to conditions, such as weather, weekly days, time, and travel purpose.

Lee (2022) noticed that the pedestrian environment serves other modes of transportation, such as bicycles, micro-mobility services, wheelchairs, and baby strollers. This means it may be more than pedestrians, and policymakers should consider this in the planning phase. The question could be: Should cities’ public administrations allow other users to utilise the sidewalks? To respond, it is important to note that allowing mixed-use sidewalks has a dual effect. If only a few individuals utilise sidewalks, it can enhance comfort (especially for males). However, increasing the number of potential users enhances both the perception of safety and the appeal of the sidewalks. This statement is in keeping with the concept of the social signifier: the presence or absence of people serves as a signifier, meaning some behaviours are socially allowed or not (Norman, 2010). Social signifiers are not guarantees, but they are strongly suggestive.

Results showed implications for practitioners. For instance, active mobility behaviour change campaigns should focus on both cycling and walking (Said, 2022). When designing a policy, decision-makers should implement an integrated approach to avoid negative effects (due to a possible shift from public transport to active mobility, which is not desirable); this integrated approach should increase infrastructure availability, foster an active mobility culture and discourage the use of cars (Pisoni, 2022).

Current bicycle users, as well as motorcycles, are not particularly sensitive to the time, speed, and distance of their trip, as their modal preference is more probably a matter of life choice. This stresses how promoting a cultural value related to walking and biking can be beneficial, and overall, this can be a very useful hint for policymakers to help promote active mobility. However, it is worth noting that the countries more mature in providing active mobility infrastructures are different from those historically famous for vehicle companies, such as Italy, France, the UK and Germany.

Finally, observing the Sustainable Development Goals, it looks clear that addressing active mobility could have a positive effect in many directions, starting from enhancing the cities’ inclusiveness and sustainability (SDG 11th), passing through the reduction of inequalities (SDG 10th) and promoting well-being and healthy lifestyle (SDG 3rd).

4.2 How were the SDGs connected to Social Sustainability?

The analysis confirmed the connection between the impacts of AM and social sustainability. This work suggests adopting active mobility data, the measurements of its impacts and the moderating variable in order to assess and benchmark part of social sustainability's complexity. Recalling the definition of social sustainability, strengthening the set of policies, rules and infrastructures that enhance accessibility and AM choices, in turn, reinforces the social dimensions of equality and inclusiveness. Therefore, active mobility data can contribute to assessing indicators 9.1.2[1], 11.2.1[2], and 16.1.4[3], while those indicators advance to qualify equity and inclusiveness measures.

Moreover, the correlation between active mobility and the openness to learn is worth mentioning. AM promotes a mindset of adaptability and innovation. By actively engaging in the environment and being physically present, individuals become more aware of their surroundings and the need for change. This mindset can extend beyond transportation and inspire a willingness to learn, adapt, and embrace new ideas and technologies. By being open to learning, individuals can contribute to long-term social sustainability through their choices and actions. In this regard, openness to learn appears to be linked to indicator 4.7.1[4].

The opportunity to interact with others in green areas can enhance people's calmness and energy levels. The restorative effect of nature, social interaction and connection, physical activity, exposure to natural light and fresh air, and the aesthetics of green spaces all play a role in promoting a sense of tranquillity and vitality. Incorporating green spaces into urban environments and encouraging their use can contribute to the well-being and social sustainability of communities. About this aspect, the indicator 11.7.1[5] can be considered as a contribution to the social sustainability.

In summary, this research highlights the links between the SDGs 11th, 9th, 4th, and 16th with the overall framework of social sustainability.

4.3 Scientific community and public engagement

In this session, we aim to explore the extent of attention dedicated by scientific journals to Active Mobility and evaluate the availability of scientific materials in terms of open-access and proprietary resources. Therefore, we analyse the knowledge accessibility for public engagement on this matter.

Tab.3 reported the references of the articles extracted, the title of the journal that published the article, its main topic and whether the articles were open-access or not.

The main sources of information are journals dealing with transportation research, followed by urban planning and medicine science. Fewer articles originated from journals relative to policy, psychological studies, and sustainability. One source was generalist.

Just 8 articles were free and available for public use, while 11 were not open access. This finding suggests that less than half of the knowledge used in this review would have been freely accessible. This can be a problem since urban planning is closely linked to public participation in decision-making and co-design of cities and policies.

Reference	Journal's title	Main Journal's topic	Open access
Giuffrida et al. (2023)	Journal of Transport Geography	It is focused on the geographical dimensions of transport, travel and mobility	No
Möllers et al. (2022)	Transportation Research Part A: Policy and Practice	It deals with policy analysis, planning, interaction with the political, socioeconomic and physical environments, and management and evaluation of transport systems.	No

1 Passenger and freight volumes, by mode of transport.
2 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities.
3 Proportion of population that feel safe walking alone around the area they live after dark.
4 Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment. This indicator appears also as the 12.8.1, 13.3.1.
5 Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities.

Reference	Journal's title	Main Journal's topic	Open access
Hasselder et al. (2022)	BMC geriatrics	It deals with all aspects of the health and healthcare of older people.	Yes
Hollenbeck et al. (2022)	Frontiers in Psychology	Clinical research, cognitive science, perception, consciousness, imaging studies, human factors, and animal cognition to social psychology.	Yes
Sundfør & Fyhri (2022)	Journal of Transport & Health	It evaluates or informs the development of interventions and policies to improve population health, or that make a genuinely original contribution.	No
Lee (2022)	Sustainability	Environmental, cultural, economic, and social sustainability of human beings.	Yes
Doi et al. (2022)	Journal of the American Medical Directors Association	The journal covers all aspects of long-term care and geriatrics.	No
van Hoef et al. (2022)	Frontiers in Psychology	Clinical research, cognitive science, perception, consciousness, imaging studies, human factors, and animal cognition to social psychology.	Yes
Kurita et al. (2022)	Journal of Cachexia, Sarcopenia and Muscle	Journal dedicated to cachexia and sarcopenia, as well as to body composition and its physiological and pathophysiological changes during the lifespan and in response to different illnesses from all fields of the life sciences.	No
Pisoni et al. (2022)	Science of the Total Environment	Journal dedicated to the total environment, which interfaces the atmosphere, lithosphere, hydrosphere, biosphere, and anthroposphere.	No
Brüchert et al. (2022)	Cities & health	Journal mainly focused on public health and the health of planetary systems.	No
Carboni et al. (2022)	Transportation research procedia	Journal mainly focused on social science area of transportation research.	Yes
Said et al. (2022)	International journal of sustainable transportation	Focuses on interactions of transportation systems with urban subsystems and publishes interdisciplinary research on global or local sustainable transportation.	No
Mehriar et al. (2021)	Applied Sciences	The journal covers all aspects of applied physics, applied chemistry, engineering, environmental and earth sciences, and applied biology.	Yes
Scorrano & Danielis (2021)	Research in Transportation Economics	The journal deals with the economic aspects of transportation, government regulatory policies regarding transportation, and issues of concern to transportation industry planners.	No
Giansoldati et al. (2021)	Research in Transportation Economics	The journal deals with the economic aspects of transportation, government regulatory policies regarding transportation, and issues of concern to transportation industry planners.	No
Brand et al. (2021)	Transportation Research Part D: Transport and Environment	It is dedicated to environmental impacts of transportation, policy responses to those impacts, and their implications for the design, planning, and management of transportation systems.	No
Fonseca et al. (2021)	ISPRS International Journal of Geo-Information	Journal of wide interest, including Spatial data modeling, Spatial data management, Spatial analysis and decision making.	Yes
Arranz-López et al. (2021)	Journal of Maps	Inter-disciplinary journal for researchers to publish maps and spatial diagrams across the physical and social sciences.	Yes

Tab.3 Sources' Journal and resource assess type

5. Conclusion

The review analysed how scientific literature quantifies Active Mobility, its antecedents, impacts, and how impacts can contribute to defining Social Sustainability. The findings of the Rapid Evident Assessment method provided a comprehensive framework of definitions, variables that influence active mobility behaviours and those influenced by it, challenges in its promotion, knowledge gaps, and correlation with SDGs.

- The comprehensive definition of Active Mobility encompasses various physical activities undertaken for transportation purposes, such as walking, cycling, e-bike, bike-sharing, and public transport. The main methods for AM assessment were surveys and diaries. Nonetheless, the assessment of Active Mobility behaviours through mobile app data is still in its early stages and faces challenges in accurately distinguishing between different modes of transportation. Further research could focus on exploring innovative and accurate data collection methods that can effectively capture Active Mobility behaviours and provide reliable insights for decision-making;

- Several variables influence Active Mobility behaviours, including behavioural science factors, urban planning considerations, and socio-demographic characteristics. Positive attitudes, work schedule flexibility, consistency between people and place identity, and satisfaction with home and infrastructure were associated with higher Active Mobility behaviours. Additionally, access to services, safety, good street maintenance, and environmental factors played a significant role;
- The impacts of Active Mobility were identified across various domains, including environmental, social, economic, health, and psychological aspects. Active Mobility contributes to equity and inclusion, promotes mental well-being, reduces CO_2 emissions, enhances physical health, and reduces external costs associated with vehicles. However, the adoption of Active Mobility is influenced by factors such as trip distance, purpose, and perceived road safety. In this regard, the use of e-bikes has the potential to change attitudes towards Active Mobility by offering a more comfortable and faster mode of transportation. Therefore, further research could involve a comparative analysis of Active Mobility initiatives implemented in different cities or regions, evaluating their outcomes, and identifying successful strategies and lessons learned;
- Challenges in promoting cycling culture and addressing safety concerns remain. Integrated transportation systems and a focus on both cycling and walking were suggested as effective strategies for promoting Active Mobility. Because of the nature of this research approach, this article could not delve deeply into the cultural factors influencing Active Mobility behaviours. Investigating cultural attitudes, values, and norms related to transportation choices and examining how cultural factors interact with other variables could provide valuable insights for designing effective interventions and policies;
- Despite the positive impacts of Active Mobility on various domains, there is limited discussion on the long-term effects of Active Mobility interventions. Therefore, further research could explore the sustainability of Active Mobility behaviours over time and investigate factors that contribute to their long-term adoption;
- The connection between Active Mobility and the Sustainable Development Goals (SDGs) was evident, with positive effects on inclusiveness, sustainability, reducing inequalities, and promoting a healthy lifestyle. The analysis also highlighted the role of Active Mobility data in assessing social sustainability indicators and promoting openness to learning and interaction in green spaces;
- Regarding the scientific community's engagement, most of the articles were published in transportation research journals, and limited open-access articles were available, posing a challenge to public engagement and participation in decision-making processes related to urban planning.

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Image sources

Figg.1 - 2: Authors' elaboration

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Redesigning "schools squares" for a public city

A proposal of classification and intervention

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Abstract

The conquest of new public spaces is one of the main options in processes of urban regeneration. It seems essential in contemporary cities, since our life occurs more and more indoors and in private contexts, reducing the role of public and outdoor activities. Among cultural-based urban regeneration projects that operate within those spaces waiting for an improvement of the existing public functions, schools can play a particularly prominent role, as well spread and symbolic institutions with an educational mission for young people. From this perspective, the paper discusses how school squares, namely the urban areas close to the entrance of schools, can be designed and regenerated to produce a real public space where the city meets the school and vice versa. The paper presents a methodology to classify different typologies of school squares, based on an extensive analysis on over 600 school squares, located in the provinces of Milan, Turin and Varese. On the basis of such classification, some guidelines are discussed in order to propose a strategy to redesign these symbolic spaces and to conquer them as public areas.

Keywords

School squares; Public spaces; Urban regeneration; Design.

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1. Urban regeneration for a public city: the case of the school squares

The paper aims at presenting a proposal to classify different typologies of urban areas related to schools and discussing some guidelines to re-design these areas in order to make them a real public space where the city meets the school and vice versa. Such reflection can be seen as part of the recent debate about some good practices of urban regeneration related to the urban spaces close to schools, quite spread in Italy (Ciaffi et al., 2022; Pileri et al., 2022; Mattioli et al., 2021; Renzoni & Savoldi, 2022) and in European and International contexts[1] (Giles-Corti et al., 2011; Goodman et al., 2021).

The conquest of new public spaces is one of the main options in processes of urban regeneration (Arendt, 1961; Lefebvre, 1976), both as a temporary and permanent strategy (Bruzzese, 2019; Lino, 2014; Zali et al., 2016). This kind of action is not just a recent approach; on the opposite, it was already studied and applied since the Sixties. In that period, Jane Jacobs published her seminal book *The Death and Life of Great American Cities* (Jacobs, 1961), where she pointed out how the dramatic increase in car traffic and the urban planning ideology of modernism, that separates the uses of the city and emphasizes free-standing individual buildings, would put an end to the urban space and city life and result in lifeless cities devoid of people. At present, after many years, this message is still actual and can inspire urban regeneration processes: the awareness of the importance of public spaces in contemporary cities should bring to the definition of public policies to design a lively, safe, sustainable and healthy city (Gehl, 2010).

Reflecting on the relevance of public areas in the city is crucial. On the one hand, since, shortly after the millennium, for the first time in history the majority of the global population became urban rather than rural (UNCTAD, 2022): cities have grown rapidly and urban growth will continue to accelerate in the years ahead. This means that cities need crucial changes to the bases for planning; they should focus on the needs of the people who will use cities increasingly. On the other hand, public spaces give planners and architects unique opportunities of designing. In this sense, it seems emblematic and still actual what Jan Gehl wrote in the introduction of his *Life between Buildings*, an interesting book where the focus is totally devoted to the public and open spaces spread all over the city: "This is not a book about "special occasions" – major events, festivals, street markets, carnivals, and block parties. Nor it is a book that concentrates on main streets and bustling city centers. Its focus is, rather, on ordinary days and the multitude of outdoor spaces that surround us. It is a book about everyday activities and their specific demands on the man-made environment" (Gehl, 1987, p.9).

Such bases give us a double point of view: (1) every outdoor place, even the residual and less relevant, can be an occasion of re-designing and re-thinking the public city; (2) we always experience the outdoor places of the city by performing daily activities. Such activities can be described as necessary (e.g., going to school or to work, shopping, waiting for a bus), optional (e.g., taking a walk to get a breath of fresh air, standing around enjoying life or sitting and sunbathing) and social (e.g., all the activities that depend on the presence of other people in public spaces, such as children at play, greetings and conversations) (Gehl, 1987). It is quite intuitive that optional and social activities take place only when urban surroundings allow them. In other words, when outdoor areas are of poor quality, only strictly necessary activities occur. Focusing on creating or re-creating urban public areas (of high quality) appears as a priority if we want to experience all the huge range of the outdoor activities.

Starting from this general framework, the specific case of the urban area related to school is chosen as emblematic to tackle the issue of reconquering public urban areas. Indeed, among cultural-based urban regeneration projects that operate within those spaces waiting for an improvement of the existing public functions, schools can play a particularly prominent role (Munarin et al., 2011; Wilson, 2005; Zhu & Lee, 2009). School, as an institution closed in its educational mission (Rossi Doria, 2015), emerges as a local cultural device that is alive and pulsating, as it enables a plurality of relations, but also project opportunities for spaces

[1] Interesting examples of projects done on public areas related to the entrance of schools are reported in Pileri et al. (2022, p. 82-109).

within and beyond the school service, embedded in the needs and requirements of the neighborhoods in which schools are located (Cannella, 2023; Cancellieri et al., 2022; Shbeeb & Awad, 2013). The deep relation between school and city was thoroughly studied (ARUP, 2017; De Maio et al., 2022). From these studies the urgency of enlarging the space of the school also in public areas of the city has emerged. Firstly, it is regarded as a right for children to experiment the city in an autonomous and safe manner (Balzani & Borgogni, 2003; Borgogni, 2016; Renzi et al., 2014; Ward & Fyson, 1973). Secondly, this specific public area is seen as essential in the growth process of children (Borgogni, 2019; Casagrandi & Pileri, 2020): for many years, everyone has to frequent schools and their proximity, while at the same time is not forced to enjoy parks, sport centers or other similar places. Therefore, the urban area related to the school is the first urban place where all children begin to experience the city (Dolto, 2000; Tonucci, 1996; Ward, 1979): here, they start to learn how to live the city in the act both of staying in that place (for instance waiting for other students or having a conversation at the end of classes) and moving, by daily repeating the commuting from home to school. In this sense, the urban surroundings of the school are essential, since they can encourage or discourage the choice of active mobility practices (Bianchi et al., 2023; Strak et al., 2018a) and, thus, influence both the psychomotor and cognitive abilities (Ross, 2007; Stark et al., 2018b) and the health (Masoumi, 2017) of the children.
Quite recently, such urban areas related to schools were defined as "school squares", namely as "public space in front of a school, regardless of whether the toponomy calls it an actual square" (Pileri et al., 2022, p. 14). In other cases, the same areas were defined as "school street" (Belingardi, 2022; Cannella, 2023; Thomas et al., 2022; Varma, 2021). The idea of the squares seems more suitable for this paper, since it emphasizes the symbolic strength of the place and its public potential. From a spatial point of view, it does not mean that these areas are squares or that they are already high-quality public areas where optional and social activities can occur. On the contrary, in many cases the urban area in front of the school entrance is just a road space, designed for cars and not for people, or in a special way for the students. These data emerged from an extensive analysis, carried out on over 600 school squares, located in the provinces of Milan, Turin and Varese (Italy). Thanks to this rich analysis, the paper discusses a proposal of classification of four different categories of school squares. On the basis of such classification, some guidelines are discussed, in order to propose a strategy to redesign school squares and to conquer this symbolic urban area.
The paper is structured as follows. A sample is presented and, subsequently, four typologies of school squares are introduced by describing their main characteristics and possible actions to transform them in real public urban places. The general proposal of classification is better analyzed thanks to four case studies, one for each typology; for each of these, we tailored a re-design program. In the conclusion, a synthesis is provided, together with possible future developments concerning other design aspects (such as those relating to how the design of the school squares as public area of high quality can influence also the daily active mobility of the children towards school).

2. The sample of the analysis and a proposal of school squares classification

The aim of the analysis was to better know the main spatial features of the school squares in the Italian context. How do they appear? Do they have some similar characteristics to cluster them? To answer these questions, an extensive investigation was carried out on 606 school squares[2], studied with a similar

[2] The study sample is located in three areas in Northern Italy, divided as follows:
- 56 municipalities of the metropolitan city of Milan, analyzed during the research project "HABITAT@SCUOLA" (research conceived due to the collaboration between the Department of Electronics, Information and Bioengineering and the Department of Architecture and Urban Studies, supported by Fondazione Cariplo in 2018-2020. The area includes the city of Milan, the municipalities of the first and second belt, the ones to the east and to the south of the metropolitan city. The squares analyzed refer to primary and secondary schools, covering the group age 6-13.
- 6 municipalities of the metropolitan city of Turin, analyzed during the research project "La città va a scuola" (research developed within the Department of Architecture and Urban Studies and supported by Fondazione Compagnia di San

methodology (site inspections and description of the spatial characteristics related to the outdoor spaces in front of the main entrance of the schools). Although it is not possible to consider it as an exhaustive and definitive analysis, it still allowed us to get some first results. One of the main outcomes is the classification of the school squares, categorized in 4 typologies, with their relative distribution (Fig.1):

- Type 1 – Sidewalk (39% of the cases, 240 out of 606 schools). It is a protected strip along the street, which develops linearly and is indifferent to the presence of a school. Hence, it is just a minimum standard school square for pupils, being more of a transit space than a place to stay;
- Type 2 - Lay-by (32% of the cases, 192 out of 606 schools). It is a localized widening of the sidewalk at the school entrance, for example a "peninsula" facing the road or an indentation obtained from setbacks of buildings, with a variety of shapes, sizes and paving. Pupils and their parents have more space than on a sidewalk and are invited to stay and spend their time there;
- Type 3 - Car park (17% of the cases, 101 out of 606 schools). It could be a public car park also used by other citizens or a specific area within the school complex with regulated access. The presence of cars and the lack of attention to pedestrians are predominant, so pupils are usually taken by adults right to the school entrance;
- Type 4 - Park or pedestrian area (12% of the cases, 73 out of 606 schools). It is a large and protected place entirely dedicated to pedestrians, like an urban park, the main square of the municipality, or an entire road closed to traffic. Here pupils can move and play freely under safe conditions and in a pleasant place.

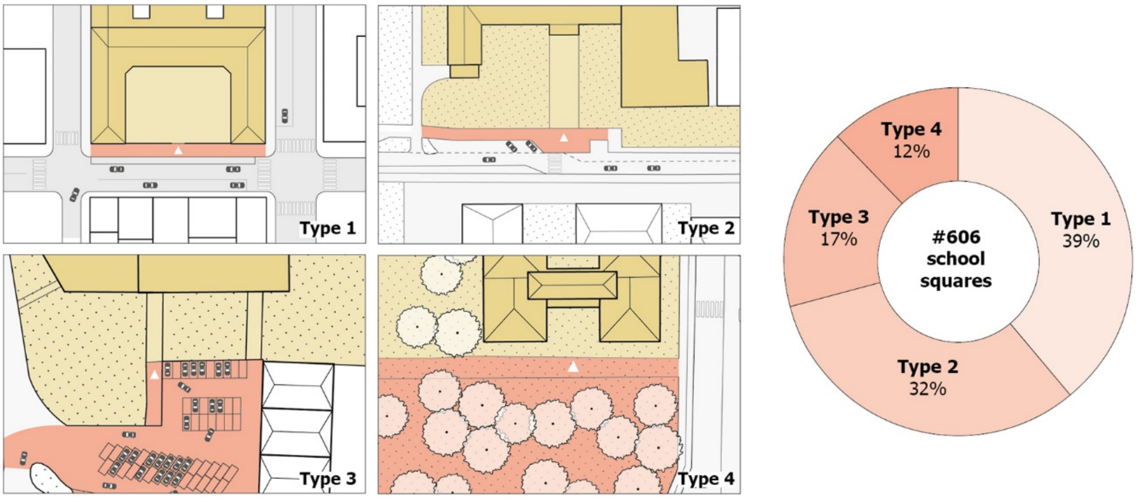

Fig.1 Types of school square (in red) and their distribution within the sample area

3. From different typologies of school squares to different public spaces and design proposals

The four types of school square seem different firstly because of the public spaces they generate. Type 1 is a typical space of transit, without any intention of being a specific outdoor area related to the entrance of a school. Likewise, Type 2, despite a widening of the sidewalk, is mainly a space of transit because the lay-by

Paolo in 2020-2021, shared with Politecnico di Torino and a diverse group of local associations coordinated by Laqup). The area includes the city of Turin and a selection of municipalities of the first belt (one north, one east, one south and two west). The squares analyzed refer to schools from nursery to high grade, covering the group age 3-18.
- 36 municipalities of the province of Varese, analyzed during the research project "MOVE ON - Mobilità leggera in valle Olona" (research developed within the Department of Architecture and Urban Studies and supported by Fondazione Cariplo and Lombardy Region in 2021-2023, coordinated with the Province of Varese and in cooperation with a broad partnership). The area includes primarily municipalities along Olona valley and a selection of other municipalities scattered in the province of Varese. The squares analyzed refer to schools from nursery to high grade, covering the group age 3-18.

is often dull and too small related to the amount of people who could frequent it. We call them "school squares", even if they do not have any spatial feature, both quantitative and qualitative, similar to such a complex and rich public area. Types 3 and 4 have spatial features more suitable for a real public space since they both present a large area exclusively dedicated to the entrance of the school. Here the difference between these two typologies can be found in the quality of the space: Type 3 can be defined as car-designed (devoted mainly to parking cars), while Type 4 as people-designed (where cars are excluded and the space can be devoted to people, students or not). In sum, different types of school squares generate different kinds of public space. A simple way to visualize such relation can be provided by the scheme of necessary, optional and social activities, discussed in the introduction (Gehl, 1976). As a matter of fact, it is possible to associate the four types of school squares with the activities that can occur or be enhanced due to the different spatial features (Fig.2).

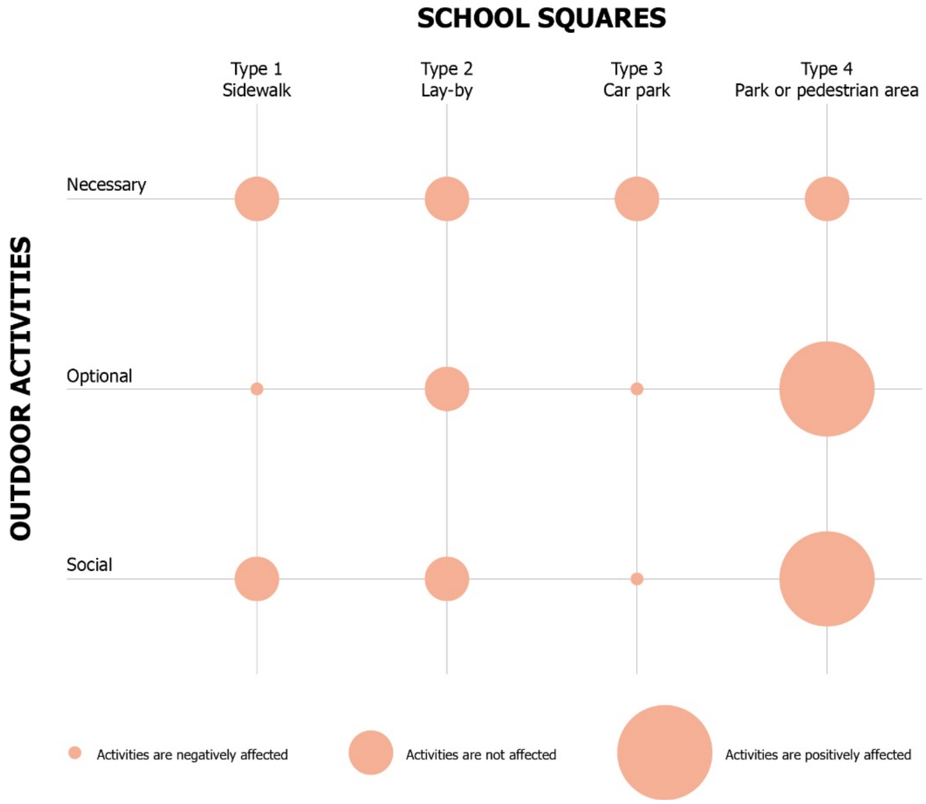

Fig.2 Correlation between the types of school square and the outdoor activities in such spaces

Fig.2 shows the correlation between the types of school square and outdoor activities: in Type 1, being the sidewalk a small line, optional activities are negatively affected; in Type 2 outdoor activities are not positively nor negatively affected by the place; in Type 3, being car-designed, optional and social activities are negatively affected; in Type 4, being people-designed, optional and social activities are positively affected. It has to be noted that necessary activities occur in every school square and are not affected by the place.

These assumptions do not consider the quality of the public spaces which, of course, plays a crucial role in affecting certain activities. However, they give us an idea of the necessity to intervene on school squares: if we really want to make them a public place where outdoor life occurs and children can experience a livable city, we need to redesign and conquer these symbolic areas. This assumption seems even more urgent considering the distribution of the typologies, from which it emerges how over 50% of the cases is represented by school squares (types 1 and 3) where almost only necessary activities can occur; on the contrary, just in 12% of the cases school squares are potentially suited for optional and social activities (Type 4).

In the next paragraphs, we discuss some interventions to make a school square a public space of good quality, namely able to enhance optional and social outdoor activities. Such interventions are applied to four specific cases, one for each type of school square. The cases will be first presented through the analysis of their specific features, by considering both the urban surroundings and the spatial characteristic of the school square. Later, the design proposal is introduced by discussing two different kinds of actions: one related to the quantitative dimension (e.g., how to enlarge and conquer more urban spaces) and another related to the qualitative aspects (e.g., how to increase the pleasantness and the livability of the space). In order to be more effective and concrete, these actions are proposed in an incremental way, from the simplest with limited outcomes (Step 1), to the most complex with more incisive results in enhancing optional and social activities (Step 4). The actions here proposed differ in outcomes, complexity degree, costs and involved actors as follows:

- Step 1 - Maintenance. Small maintenance and management interventions carried out by the school, to make the school square tidier and inviting (e.g., maintenance of fences, decoration of the walls, waste management). The greater care towards this place invites people to live it and to take care of it in turn, experiencing it actively;
- Step 2 - Appropriation. Temporary interventions to test a new school square (e.g., temporary closure of the road, furnishing, ground painting), designed and implemented in collaboration with the school, the community and the administration. These are "tests" for future interventions, which involve the participation of many citizens;
- Step 3 - Upgrade. Definitive interventions on the school square, carried out by the administration in collaboration with the school and with the support of professionals such as architects and urban planners (e.g., sidewalk widening, repaving, furnishing, planting greenery). Optional and social activities are encouraged by the fact that more space and better quality are reserved for people;
- Step 4 - Encroachment. Definitive interventions on the entire street of the school square, carried out by the administration with the support of professional such as architects and urban planners (e.g., road section redesign, traffic calming interventions, definitive closure of the road). Vehicular traffic is physically inhibited, thus even more space and better quality are reserved for people, both in front of the school and in the surrounding areas.

Step 1 includes interventions on qualitative aspects, while Step 4 on quantitative and spatial extension of the school square; steps 2 and 3 comprise both qualitative and quantitative actions, respectively developed in a temporary and permanent way.

3.1 Type 1 - Sidewalk: the case of Martiri della Resistenza Primary School (Lonate Ceppino, VA)

The "Martiri della Resistenza" Primary School (M.R. School) is taken as example of a sidewalk school square (Type 1). It is located in Lonate Ceppino, a small municipality with ca. 5,000 inhabitants in province of Varese (Fig.3).

M.R. School, attended by 102 pupils (Ministero dell'Istruzione e del Merito, 2023), serves the peripheral S. Lucio district, while the only other primary school of the town is in the center. M.R. School and its school square are located in a block with different kind of sport services as the sports field, the tennis club and the municipal gym, surrounded by residential buildings; they are accessible from the east side through a two-way street that connects several blocks of houses (via S. Lucio, a cross street of the provincial road via Piave), which becomes one-way for a 130-meter stretch in front of the school. This part of via S. Lucio is a long straight line of 350 m along which cars tend to speed up; at the school entrance there is a raised crosswalk slowing down the speed but, actually, its design is not functional for this purpose because the height difference is too low, and the crosswalk approach ramp is too short. Along via S. Lucio there is also a cycle path that connects the neighborhood with the center, and we can also find bicycle racks in the schoolyard.

Fig.3 Martiri della Resistenza Primary School in Lonate Ceppino (VA)

The school square consists of a section of the sidewalk at the school entrance, 45 meters long and 1.8 meters wide, with a surface area of approx. 80 sqm (on average 0.8 sqm available for each pupil). The sidewalk in this section can be used by bicycles as well, and it is covered with smooth red paint to be more recognizable within the urban context; nevertheless, this feature does not help increase the sense of identity to the school and its school square. On the contrary, we noted the absence of a coherent design that confers a sense of place and, instead, we observed many different paving materials (such as cobblestones, pebbles, stone, traditional and colored asphalt). Along the school square there are 13 parking spots separating the sidewalk from the street, and other 22 can be found along the sidewalk of via S. Lucio; plus, there is a large parking area with 39 spots 250 meters away from the school entrance and another one with 26 spots inside the schoolyard. There is no greenery or furnishing on the school square, just a pin board and some signage; occasionally there are big rubbish bins for door-to-door collection. During the peak hour of school entry, most of the pupils enter the school yard, probably because there is not enough room outside and because the school square is not a suitable place for them: this type of school square encourages mainly necessary activities. Additionally, the road is crowded with the cars of the parents, either in transit or parked, making the space around the school square dangerous, chaotic and noisy.

The school square at the M.R. School in Lonate Ceppino needs substantial redesign, and similarly, mobility in the surrounding areas also needs it. The interventions on the school square at the M.R. School could take place as follows (Fig.4):

- Step 1 - Repainting and reordering the school fence, removing the big rubbish bins for door-to-door collection and changing the waste management method;
- Step 2 - Implementing the current school square with some space temporarily subtracted from the car parks in front of the school (13 spots);
- Step 3 - Setting up a permanent school square at the school entrance removing car parks (13 spots). Fixing the crossing by lengthening the bump ramp, so that cars would slow down before they reach the crosswalk, and increasing the height difference between the new school square and the crossing; repaving the sidewalks and the school square with consistent materials. In addition, providing the new school square with benches and greenery, and removing poles and other obstructions;
- Step 4 - Redesigning via S. Lucio permanently with traffic calming interventions (e.g., chicanes) to slow cars down; extending the school square to the entrances of the other activities on the street, removing the car parks (35 spots); repaving the new extended school square with consistent materials, removing poles and other obstructions. Consequently, rethinking of the whole mobility at urban level.

(a)

(b)

Fig.4 (a) M.R. school square in the current state and (b) with the project proposal

3.2 Type 2 - Lay-by: the case of G. Rodari Primary School (Pioltello, MI)

The "G. Rodari" Primary School (G.R. School) is taken as example of a lay-by school square (Type 2). It is located in in Pioltello, a municipality with over 36,000 inhabitants in the east of Milan (Fig.5).

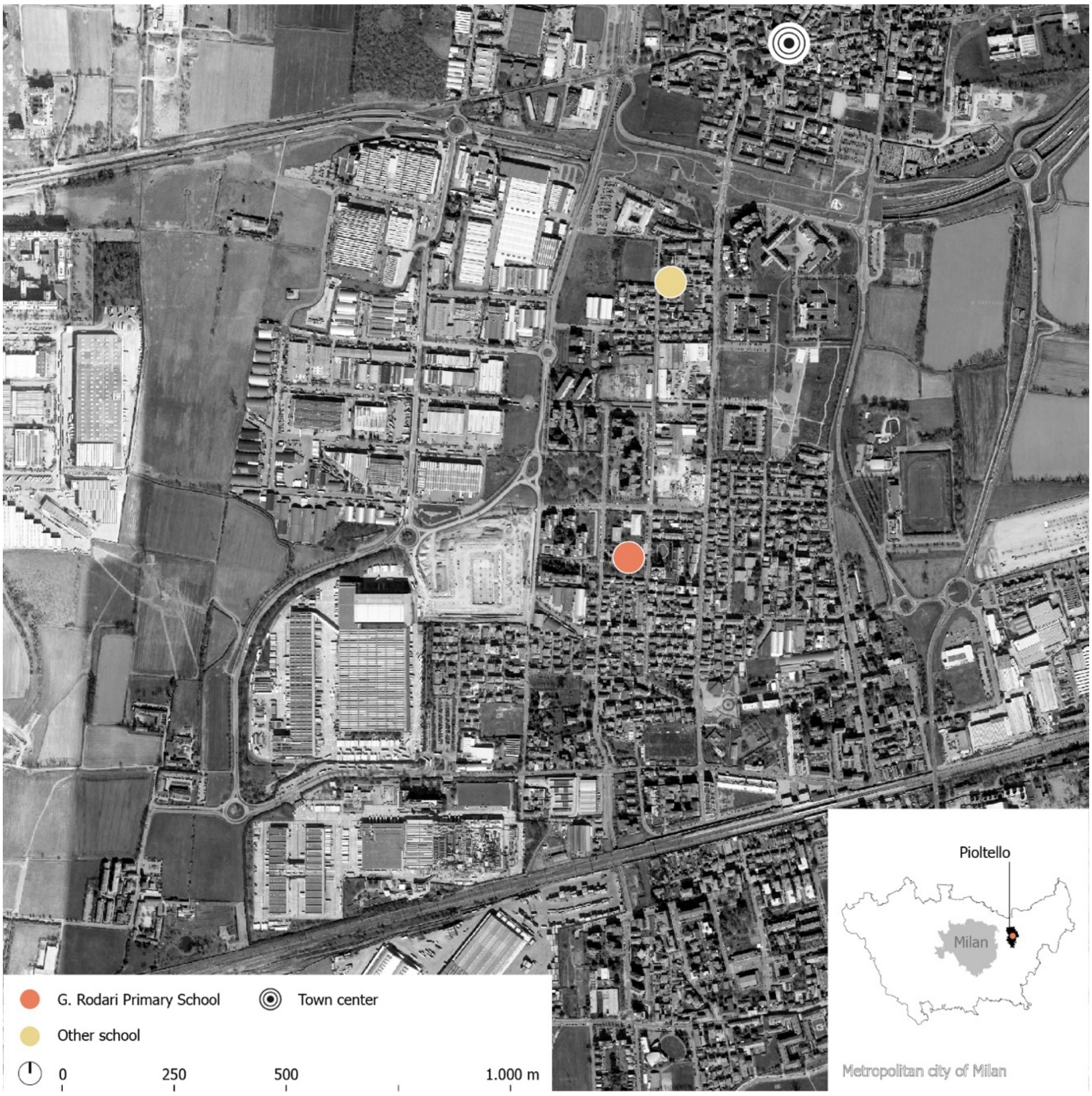

Fig.5 G. Rodari Primary School in Pioltello (MI)

G.R. School is attended by 197 pupils (Ministero dell'Istruzione e del Merito, 2023); it is one of the six primary schools in Pioltello and one of the three in the southern and peripheral area of the town. G.R. School and its school square are located in a residential area adjacent to an industrial area and are accessible from the east side through a two-ways street that connects several blocks of houses and warehouses (via G. Galilei). In the same area there is also the kindergarten "W. Tobagi" with an access on via W. Tobagi, perpendicular to via G. Galilei and equipped with five raised crossings, and the public park "A. Frank" with an access on via G. Galilei right on the opposite side from the school square to which is connected by a raised crossing.

The school square is a "peninsula" on via G. Galilei with a surface area of approx. 220 sqm (on average 1 sqm available for each pupil), it has an irregular shape given by the setback of the school's fence and it is highly recognizable thanks to the pattern of the paving, the same we found in part of the schoolyard and in front of the kindergarten, that makes it a landmark compared to the surrounding areas. There is no greenery or furnishing (present, however, in the schoolyard along with bicycle racks), just a pin board, three rubbish bins and some signage. During the peak hour of school entry, a part of the schoolchildren stays in the school square (where necessary and optional activities are performed), another part plays in the park, and others enter the schoolyard; via G. Galilei is temporarily closed to traffic in a section of 100 m between via Udine and via Arezzo, so parents are used to stopping their cars at the road closure barriers. It emerges that, on one hand, the road section closed to traffic encourages children to socialize and play safely, while on the other hand the section open to traffic is still crowded with cars.

Fig.6 (a) G.R. school square in the current state and (b) with the project proposal

Therefore, such a partial and temporary closure of the road, that expands the school square for just one hour in the entire day, is not enough to make a proper school square, which should be an important place for the city and for the extended community, and also fails to support active mobility practices. Interventions on the school square at the G.R. School in Pioltello could take place as follows (Fig.6):

- Step 1 - Repainting and reordering the school fence, keeping the pavement clean, maintaining vegetation facing the road;
- Step 2 - Implementing the current school square with some space temporarily subtracted from the car parks close to the lay-by and to the park (19 spots), beyond the existing traffic closure time on this road;

- Step 3 - Setting up a permanent school square removing car parks (19 spots) and replacing them with an extension of the lay-by; repaving the road section between the lay-by and the park (approx. 30 m) making it coplanar to the sidewalks; removing poles and other obstacles from the lay-by;
- Step 4 - Closing via Galilei between via Udine and via W. Tobagi permanently, maintaining the access just for the owners of driveways; repaving the road section between the school and the park (approx. 50 m) making it coplanar to the sidewalks; widening the sidewalks on via G. Galilei by permanently removing 60 parking spaces along the street; eliminating changes in elevation or interruptions in sidewalks at driveways in via G. Galilei, so that they are easier for pedestrians (including the disabled) to cross.

3.3 Type 3 - Car park: the case of I. Alpi Secondary School (Trezzano Rosa, MI)

The "I. Alpi" Secondary School (I.A. School) is taken as example of a car park school square (Type 3). It is located in Trezzano Rosa, a small municipality with ca. 5,400 inhabitants in metropolitan city of Milan (Fig.7).

Fig.7 I. Alpi Secondary School in Trezzano Rosa (MI)

I.A. School is attended by 244 pupils (Ministero dell'Istruzione e del Merito, 2023) and is the only secondary school in the town. I.A. School and its school square are located in a suburban area south of the city, outside the urban fabric and surrounded by agricultural fields; in the same area, there is also the urban park "Volano Oasi Naturalistica" of 4.3 ha and the municipal sport field "G. Facchetti" with a 74 spots car park. The school is accessible from the north side through a two-way street with a dead end (via G. Brambati), along which there is a cycle path ca. 150 m long between the school and the nearest neighborhood.

The school square consists of a car park within the school complex, with 62 spots and a school bus space, with a surface area of approx. 2300 sqm (on average 9.4 sqm available for each pupil). However, over the 90% of the area is conceived for the cars and a general lack of quality and sense of identity has been noted, since every element on the school square is related to the presence of adults and their cars (e.g., bollards, billboards, horizontal and vertical signage). Consequently, despite of the large size of the school square, this type allows only necessary activities: in fact, during the peak hour of school entry most of the pupils enter in the school yard (equipped with greenery and bicycle racks), since the school square is crowded with cars, either in transit or parked, making it dangerous, chaotic and noisy. Of course, the peripheral location of the school and the lack of slow mobility connections with the city are important issues that impact on encouraging car use, and practices related to active mobility are difficult to be activated.

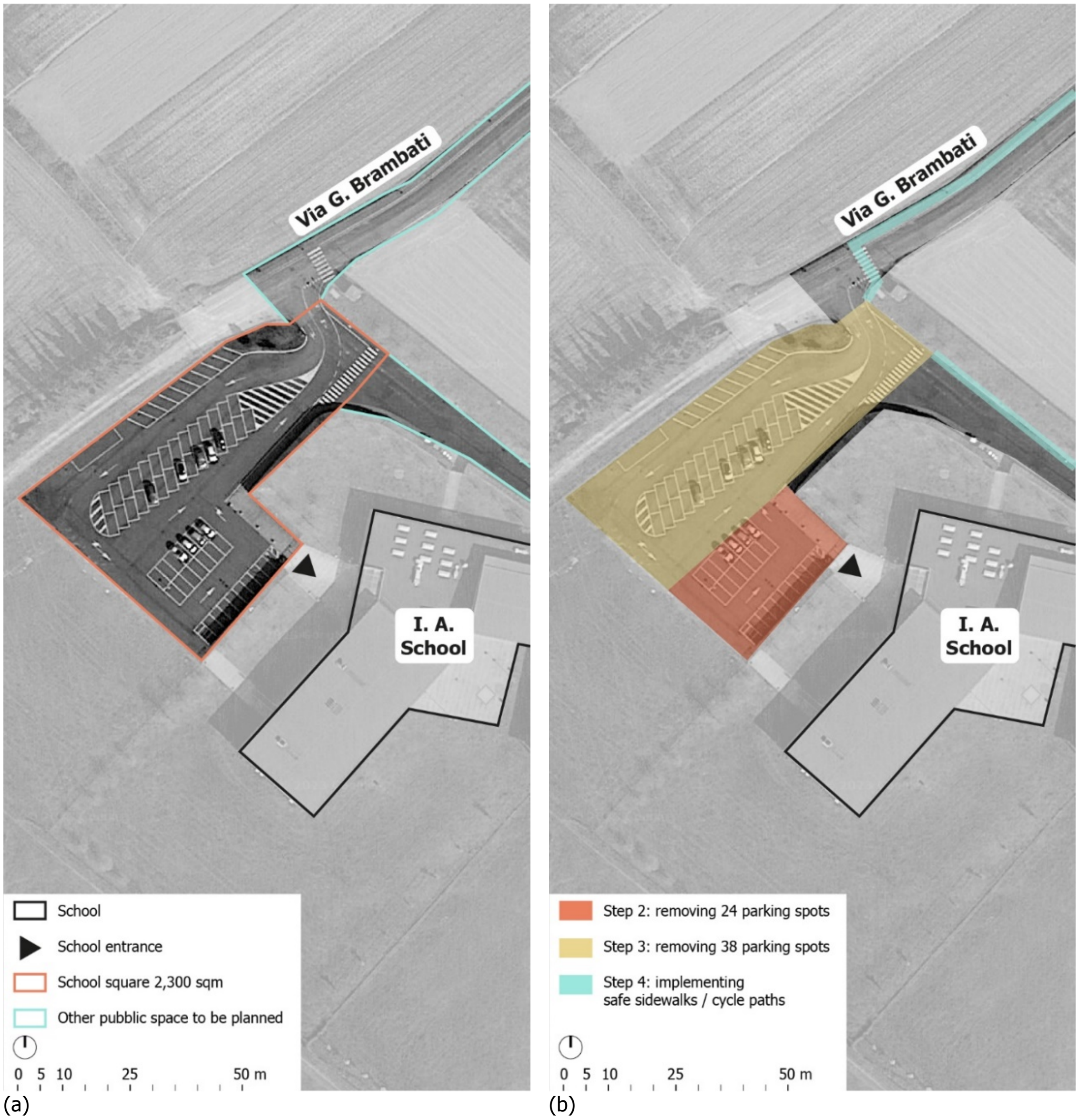

Fig.8 (a) I.A. school square in the current state and (b) with the project proposal

The school square at the I.A. School in Trezzano Rosa and the general urban mobility need a radical intervention, which could take place as follows (Fig.8):

- Step 1 - Repainting and reordering the bollards (maybe with pupils' help), removing the big rubbish bins for door-to-door collection and changing waste management, doing maintenance of the school hedges;
- Step 2 - Temporarily removing the car parks at the school entrance (24 spots) and setting up the resulting space with benches, play equipment and colored pavement;
- Step 3 - Permanently removing the car parks at the school entrance (24 spots) and setting up the resulting space with benches, play equipment and a new pavement; removing unnecessary poles and bollards. In addition, temporarily removing the remaining car parks (38 spots) making it possible to park at the sport field, ca. 400 m away;
- Step 4 - Redesigning the whole school square permanently and adding greenery (maybe de-paving some portions of asphalt), shading, play equipment and new pavement, drawing inspiration from case studies already implemented in Northern Europe (Pileri et al., 2022). Implementing safe sidewalks/cycle paths toward the sport field and the town center, to recompose the fragmentation of the existing infrastructures for the youngest.

3.4 Type 4 - Park or pedestrian area: the case of L. Moglia Primary School (Collegno, TO)

The "L. Moglia" Primary School (L.M. School) is taken as example of a park school square (Type 4). It is located in Collegno, a belt municipality with over 48,000 inhabitants in the east border of Turin (Fig.9).
L.M. School is attended by 104 pupils (Ministero dell'Istruzione e del Merito, 2023); it is one of the ten primary schools in Collegno and one of the six located along the major thoroughfare "corso Francia" starting from the center of Turin and connecting three different municipalities. L.M. School and its school square are located in a mainly residential area and are accessible from the south side through a two-way street that connects several blocks of houses (via C. Battisti) and from the north side through a dead-end street with a car park (via Bolzano, a cross street of corso Francia). The school square consists of the park "Martiri XXX aprile", with a surface area of approx. 1,600 sqm (on average 15 sqm available for each pupil): it is a green area with trees, equipped with benches and play equipment, a pleasant place to spend time despite some signs of carelessness (e.g., dirty and uneven pavements, scarped and written walls, garbage). An observation conducted during the peak hour of school entry shows that a part of the schoolchildren experiences the school square as a quiet and protected place to wait for classes to begin, where absence of cars makes room for optional and social activities; however, other pupils tend to immediately enter the schoolyard identifying this very yard as their comfort zone. It was also noted how the surrounding streets (via C. Battisti and via Bolzano) are invaded by cars, either in transit or parked, of parents accompanying their children up to the threshold of the school square, making the space around the school square dangerous, chaotic and noisy.
Although the school square at the L.M. School in Collegno belongs to a typology (the park) that already involves the presence of a good place to stay and is a potential activator of optional and social activities, it emerges that interventions are still needed so that this square can be a relevant place for both schoolchildren and the extended community. Interventions on the school square at the L.M. School could take place as follows (Fig.10):

- Step 1 - Removing the garbage, keeping the pavement and garden clean, repainting the school wall;
- Step 2 - Coloring the pavement of pathways, playground area and by the school gate, activating the involvement of pupils and increasing their sense of belonging to the place. Furthermore, outdoor activities related to the school's educational offerings could be organized so that schoolchildren can easily become familiar with the city's public space and feel like protagonists;

- Step 3 - Doing maintenance of greenery, seating and play equipment of the school square (e.g., removing graffiti, repainting, fixing…); removing car parks near the school square (20 spots not regulated by signage on via C. Battisti and 10 spots on via Bolzano) and installing bicycle racks that are safe, easy to use and do not obstruct the passage of pedestrians (since there are none in the schoolyard either);
- Step 4 - Intervening on the sidewalks and roads around the school, making them safer and more pleasant for active mobility and inhibiting vehicular traffic. Widening the sidewalks on via C. Battisti by permanently removing 40 parking spaces on the north side of the street (the same side of the school), while regulating parking that is currently self-managed on the south side; securing the three crosswalks along the street by making them coplanar with the sidewalks and creating elevation changes on the driveway surface (thus slowing down passing cars); eliminating changes in elevation or interruptions in sidewalks at driveways so that they are easier for pedestrians (including the disabled) to cross. Permanently removing 20 parking spaces by the park in via Bolzano and projecting the resulting space as an integrating part of the school square. Repaving sidewalks, pathways and school doorstep in a consistent way.

Fig.9 L. Moglia Primary School in Collegno (TO)

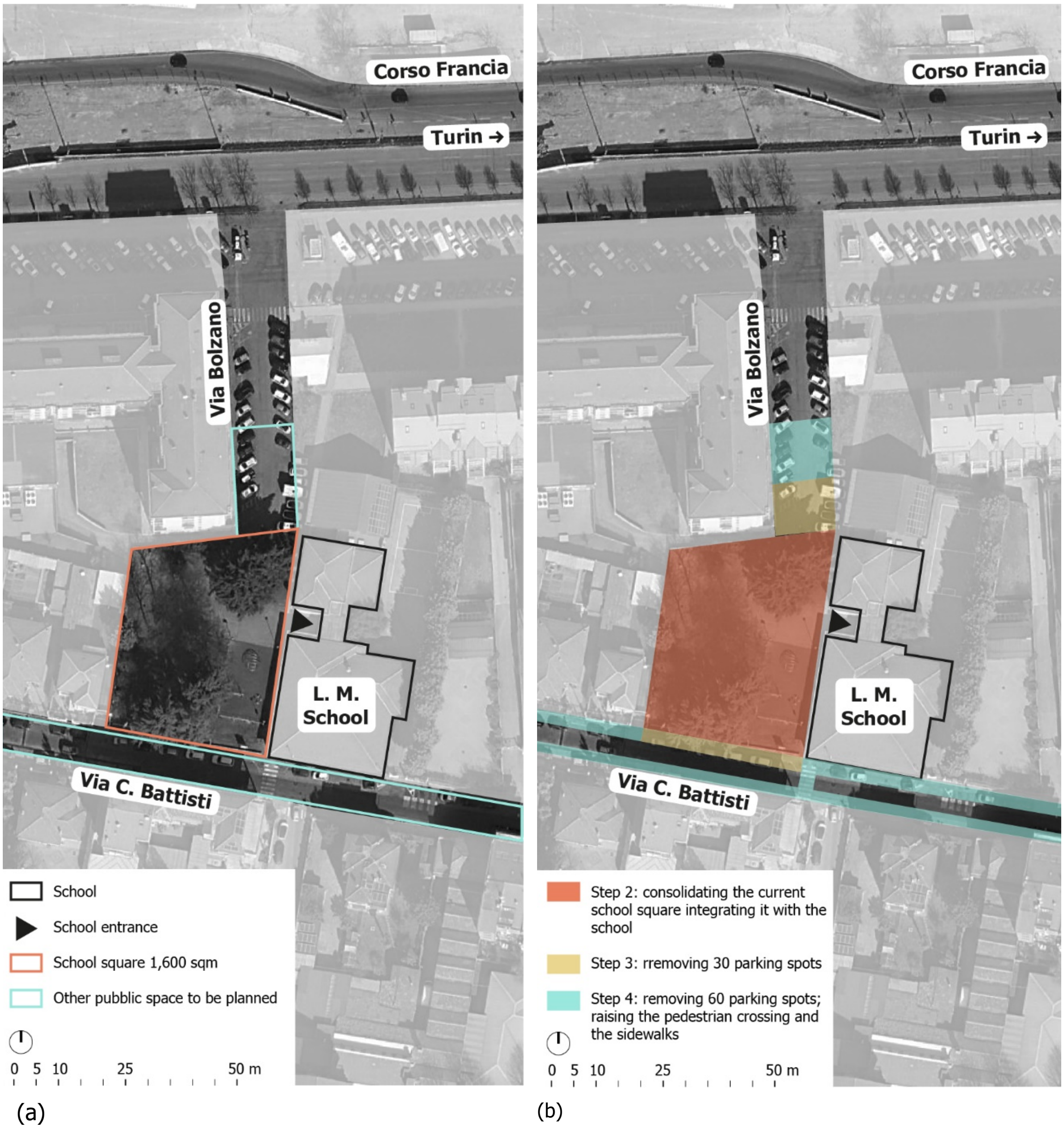

Fig.10 (a) L.M. school square in the current state and (b) with the project proposal

4. Conclusion: redesigning school squares as a place to live and move

The paper has presented a proposal to classify different typologies of urban areas related to schools, according to their spatial features, and to introduce some guidelines to re-design these areas in order to make them public spaces of good quality, namely able to encourage outdoor activities and livable cities. The results of the analysis on over 600 school squares in Northern Italy show how the four detected types are in different ways suitable for outdoor activities and can enhance or discourage them. The identification of the types of school squares is quite innovative since does not have any reference in other research, as similar classifications were done just for the schoolyards, being the playground spaces inside the school (Andersen et al., 2015; Anthamatten et al., 2015).

The same classification was already discussed by the authors by questioning how school squares, in their spatial features, can became triggers of the so-called active mobility[3] (Bianchi & Moscarelli, 2024). By crossing

[3] Active mobility, a branch of sustainable mobility, includes physical activity and non-motorized transport means, for example cycling and walking, but also all the recent human-powered variants (e.g., push scooter, roller skates/roller blades and skateboards (Scotini et al., 2017; Maltese et al., 2021).

two different approaches, one focusing on the analysis of the school square seen as a public space (proposed in this paper), thus as a place of staying, and the other where school square is seen as a starting or arrival point of daily movements, thus as a place that can encourage some modal choices, an interesting result emerges. Those types of school squares that are more suitable for every kind of outdoor activities are also more suitable for active mobility and, vice versa, those types which discourage optional and social activities, discourage active mobility as well (Fig.11).

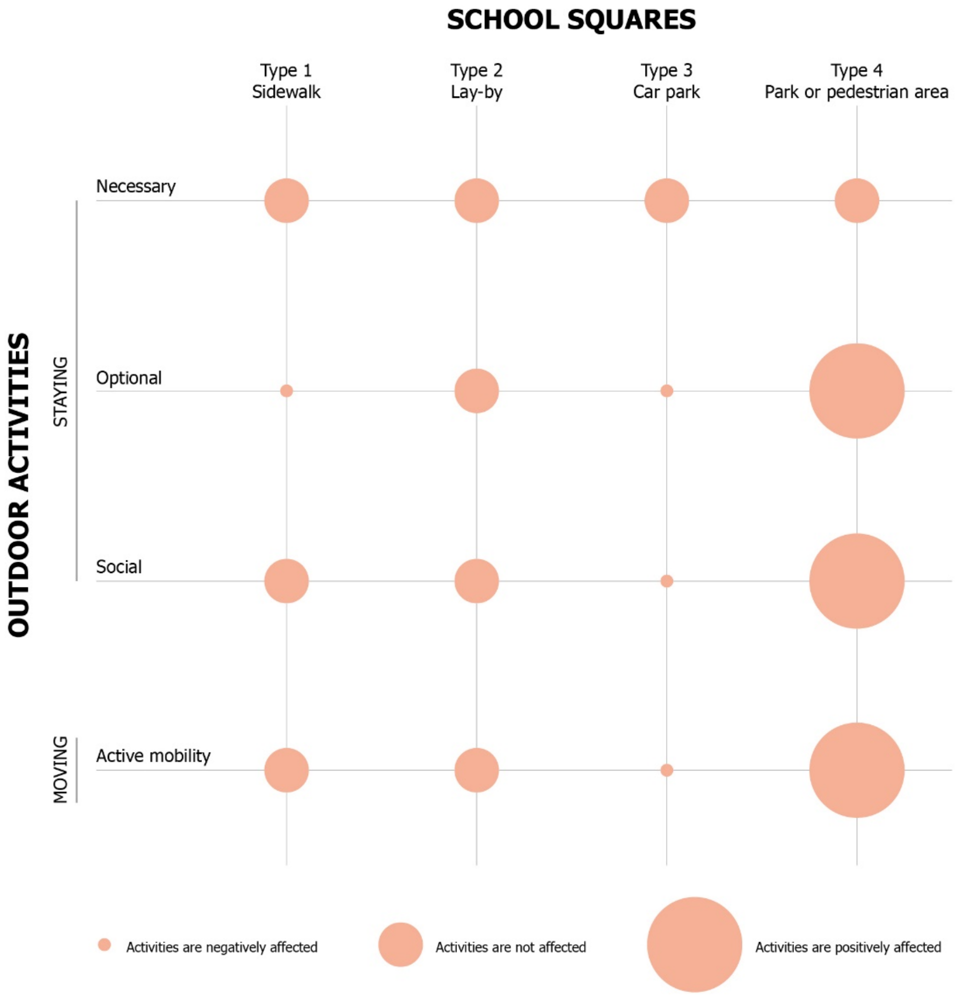

Fig.11 Correlation between the four types of school squares and active mobility, implementing Fig.2

Fig.11, by improving the Fig.2, implements the correlation between the four types of school square and the outdoor activities that may or may not occur (Fig.12): active mobility has a neutral correlation with school squares of types 1 and 2 since these types do not encourage nor discourage this practice; Type 3 negatively affects active mobility practices since is car-designed and little space is left to pedestrians and cyclists; on the contrary, Type 4 provides plenty of space to be experienced on foot or by bicycle and, consequently, enhances active mobility.

Fig.12 shows a sidewalk as a school square, where occur necessary and social activities; optional activities are inhibited, while active mobility is not encouraged nor discouraged.

The fact that a public space of high quality can influence the modal choice and in particular the choice of moving by bike or on foot is confirmed by several studies that have investigated the correlation between active mobility and urban context (Carlson et al., 2016; Wang at al., 2016). The analysis proposed here is just a first attempt to introduce this complex correlation and should be deepened with other specific studies able to consider not only the spatial features but also more in detail the presence and the quality of the physical and symbolic affordances in the school squares (partially discussed in Bianchi et al., 2023).

Fig.12 An example of a school square belonging to Type 1 - Sidewalk

Beyond the analytical part, the other relevant result discussed in the paper concerns the strategies to redesign school squares as public spaces of high quality. As we have seen in each case study, the school square of every type could be improved, through actions both on the extension of the area and on the qualitative aspects. Also, in this case there are some limits that have to be declared: one is of course the fact that the redesign proposals are just general guidelines, useful to identify some categories of possible actions, but not perfectly tailored on each specific case which requires, as seen, accurate analysis and unique solutions. For this reason, the design proposal presented in the paper do not have to be intended as prototypical interventions suitable for every context; instead, what emerges is the necessity of a complex and multidisciplinary approach toward the project of school squares, and generally of public spaces, requiring a deep knowledge of the place and how people live it.

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The authors have shared the concept of the paper. F.B. has written the paragraphs 2 and 3. R.M. has written the paragraphs 1 and 4. The part written by R.M. is a result of the study carried out within the MOST – Sustainable Mobility National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1033 17/06/2022, CN00000023). This manuscript reflects only the author’ views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

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Fig.1: Elaboration by authors.

Fig.2: Elaboration by authors, based on Gehl, 1976.

Fig.3: Elaboration by authors.

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Fig.10: Elaboration by authors.
Fig.11: Elaboration by authors, based on Gehl, 1997 and Bianchi & Moscarelli, n.d.
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Towards more walkable streets. An assessment method applied to school areas in Parma

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Abstract
It is well known that urban areas near schools are often characterised by excessive motorised traffic, making access to school facilities difficult and dangerous on foot, especially for children. Increasing walkability of these areas can indeed lead to multiple benefits: safer streets, cleaner air, a more pleasant public space that encourages social uses and the adoption of healthier lifestyles. For these reasons, scientific literature has recently focused on school streets/squares, and their possible regeneration, also through tactical urbanism. Even Italian legislation have recently introduced the concept of "school zones".
Methods and tools are, therefore, needed to delimitate these zones and assess their walkability and quality to select appropriate interventions.
Within this framework, the paper applies a GIS-based methodology to calculate a School Walkability Index (SWI), providing a score for catchment areas around schools. The method is applied in the 3-, 10- and 15-minute pedestrian isochrones around primary schools in Parma. Data to perform the walkability assessment have been collected through in-field inspections. This evaluation enables the identification of low walkability levels and punctual criticalities. The outcomes of the research can be helpful to public administrations engaged in improving school accessibility and the social vocation of the surrounding public spaces.

Keywords
Walkability; Primary schools; GIS.

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1. Introduction

Already in 1975, traffic psychologist Stina Sandels concluded that 'even the best road safety education cannot adapt a child to modern traffic, so traffic has to be adapted to the child' (Sandels, 1975). And in 1996, the third edition of the Living and Walking in Cities Conference organised by the *Centro Studi Città Amica* (CeSCAm) at the University of Brescia already titled 'Going to School', addressing possible interventions to remodel the city looking at children safety to and around school areas (Busi & Ventura, 1996). Indeed, active mobility is a crucial strategy for encouraging children's physical activity and wellbeing, as well as for supporting decarbonisation actions, but it requires supportive environments that allow children to walk safely and comfortably. The role of schools siting and street design and their effects on the potential to walk to school is well established in the literature (Aynaz Lotfata et al., 2023; Giles-Corti et al., 2011; Rodriguez et al., 2009; Thomas et al., 2022), and nowadays schools are still among the best locations to start street transformations. As everybody could understand, children are the most important road users around schools and should be protected (Alam, 2022). It is well known that urban areas near schools are often characterised by car traffic congestion, especially at specific times of the day, causing inconvenience for children and their carers in terms of accessibility on foot, but also impacting the environment. This condition also prevents these urban spaces from being used for different purposes: social, educational, or recreational. Recent literature on the subject is increasingly focusing on *school streets* or *school squares* as ways to reinvent urban areas around school facilities, also considering tactical urban planning interventions, as those enhanced during the pandemic (City of Victoria, 2019; D'Amico, 2024; Lydon & Garcia, 2015; Hopkinson et al., 2021; Pileri et al., 2022; Sangalli & Pinzuti, 2021). Furthermore, as reminded by Bertolini (Bertolini, 2020), *play streets*, i.e., the temporarily closure of entire streets to motorised traffic to give children more space to play, are currently experiencing a revival in many parts of the world, usually as a result of citizen initiatives, with significant positive effects on physical activity, safety, social interaction, and social capital. Even in Italian legislation, particular emphasis has recently been placed on the issue. In fact, the "school zone" has been officially included within the Italian Street Code by the Legislative Decree n. 76/2020. This law recently defined "school zones" as urban areas close to school buildings, in which special protection for pedestrians and the environment is guaranteed, delimited along the access roads by appropriate start and end signs. Within this framework, this paper defines a School Walkability Index approach, that could be applied to priorities urban interventions on the road space around school areas. The index was applied to each road segment within pedestrian catchment areas around 21 primary schools in the city of Parma (Italy) to define a comprehensive pedestrian friendliness score of each analysed school catchment area.

The paper is structured as follows: section 2 presents the case study of Parma and the materials and methods applied to evaluate the School Walkability Index. Section 3 shows the results and provides a discussion in terms of quantitative and qualitative walkability assessment around the analysed schools, and finally section 4 concludes the work by presenting future research steps.

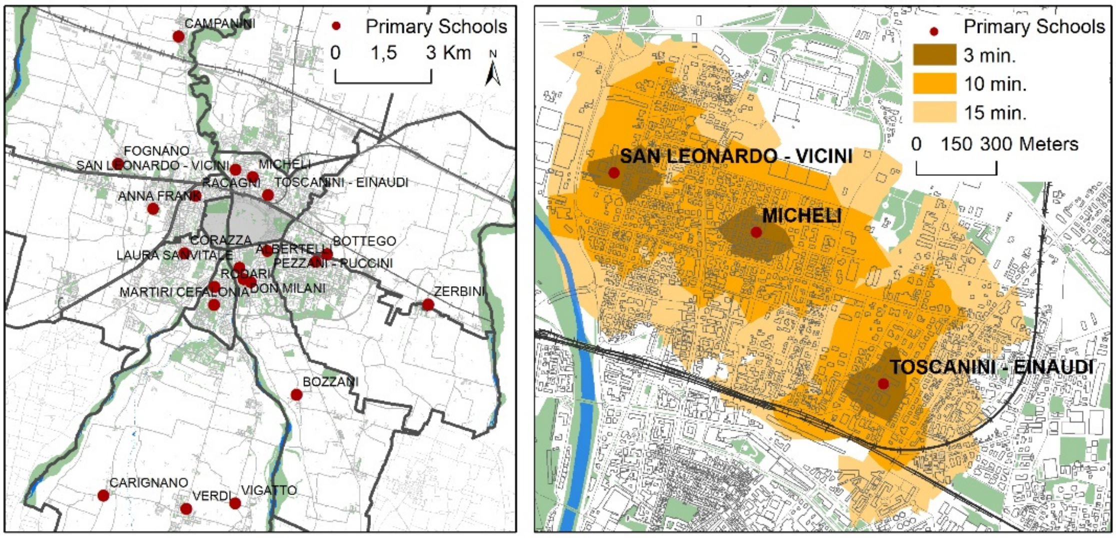
2. Materials and methods

2.1 The case study of primary schools in Parma

Parma is a medium-sized city located in the Emilia-Romagna Region, in the north of Italy. In 2023, the city[1] counts 198,431 inhabitants, 8,605 of which are children in the primary school age (6-10 years old), and it is divided in 13 neighborhoods. For this analysis, 21 elementary schools were selected (Fig.1a), including all the primary schools located within the city (both public and private ones), except for primary schools located in

[1] Data referred to January 2023 taken from the Parma Open Data Portal (source: https://opendata.comune.parma.it/dataset/popolazione-residente-al-1-gennaio-2023 accessed in May 2023).

the historical center ('Oltretorrente' and 'Parma Centro' neighborhoods), since walkability issues within the historic city presents specific peculiarities that could be addressed through more detailed approaches (see, i.a., Caselli et al., 2021). For each of the analysed schools, specific isochrones were defined considering a child walking at 3 km/h and adopting a GIS-based network analysis methodology (Caselli et al., 2021; Rossetti et al., 2020). Considered isochrones reflects a 3 min. – to define the closest urban area around the schools - 10 min. and 15 min. walking time to and from schools (Fig.1b) - values considered in the literature as optimal catchment areas for primary schools (Mercandino, 2006; ORL-ETH Zürich).



(a) (b)

Fig.1 (a) Location of the 21 analysed primary schools within the neighbourhood of Parma; (b) example of the 3-, 10- and 15-minutes walking catchment areas for some of the schools (San Leonardo-Vicini, Micheli and Toscanini-Einaudi) (on the right)

Attribute	Qualitative evaluation	Quantitative evaluation
Pedestrian/Vehicle-allowed	Only pedestrians allowed/Vehicles allowed	P / V
L1-Sidewalk provision	No/Only one side/Both side	-1/1/2
L2-Sidewalk width	No/ Only one side >90cm <1.50m/ Only one side >1.50m/ Both side >90cm <1.50m/Both side >1,50m	-1/0.5/1/ 1.5/2
L3-Ramps provision	Absent/Present	-1/1
L4-Presence of obstacles	Present/Absent	-1/1
L5-Surface maintenance	Poor/Good	-1/1
L6-Continuity	Absent/Present	-1/1
L7-Presence of parking	Present/Absent	-1/1
C1-Crossing provision	Absent/Present	-1/1
C2-Access ramp provision	Absent/Present	-1/1
C3-Crossing maintenance	Poor/Good	-1/1
C4-Crossing length	Excessive/Regular	-1/1
C5-Visibility	Poor/Good	-1/1

Tab.1 Selected attributes and related evaluation for the walkability assessment in the catchment areas of each analysed school

Within those isochrones, roads inspections were carried out to gather specific data on the pedestrian paths available and on their walkability levels. Detailed field inspections gathered information on each road segment within each isochrone, considering several infrastructural elements (e.g. road type; carriageway width, sidewalk provision and widths, presence of crossings, ramps, lightings, possible presence of obstacles, maintenance and paving factors, continuity), as well as factors related to the urban environment (e.g. buildings types, land uses, presence of public services and facilities) (Campisi et al., 2021; Ignaccolo et al., 2020; Lee et al., 2020; Torrisi et al., 2022). Each of these attributes was evaluated qualitatively and quantitatively, attributing a numerical value according to the observed description of the considered attribute. The numerical value is lower if the condition of the attribute is negative, and vice versa. Tab.1 summarises the attributes used for the evaluation.

2.2 School Walkability Index (SWI)

To consider the characteristics detected along the pedestrian routes in an aggregate way, a global walkability index was calculated for both vehicular and pedestrian-restricted links. This index was defined as "School Walkability Index" (SWI), as it aims to assess walkability at the catchment areas of each analysed school. In fact, the numerical evaluation assigned to the considered attributes took this into account, i.e. the presence of parking is considered in a negative sense since it would be advisable to encourage soft mobility (i.e. walking and cycling) and discourage the use of private cars to take children to school, and moreover to stop in its immediate surroundings. The calculation of SWI for vehicular links was performed following Equation 1:

$$SWI_{vehic} = L_1 * \left(1 + \frac{\sum_{n=2}^{7} L_n}{9}\right) + C_1 * \left(1 + \frac{\sum_{n=2}^{5} C_n}{4}\right) \tag{1}$$

where the numbers 9 and 4 respectively correspond to the maximum values that links and crossings' attributes can assume. Then, the obtained SWIs were normalised between 0 to 1.

The SWI for pedestrian links was considered equal to the maximum normalised value of 1, increasing it by 0.5 in the case of good surface maintenance.

3. Results and Discussions

This session reports the main results obtained for the analysed case study, presented through the elaboration of thematic maps. Using a GIS software, a spatial analysis was conducted with georeferenced data, linking the database of attributes to the road network graph through a joint based on the IDJ parameter, associated with each link.

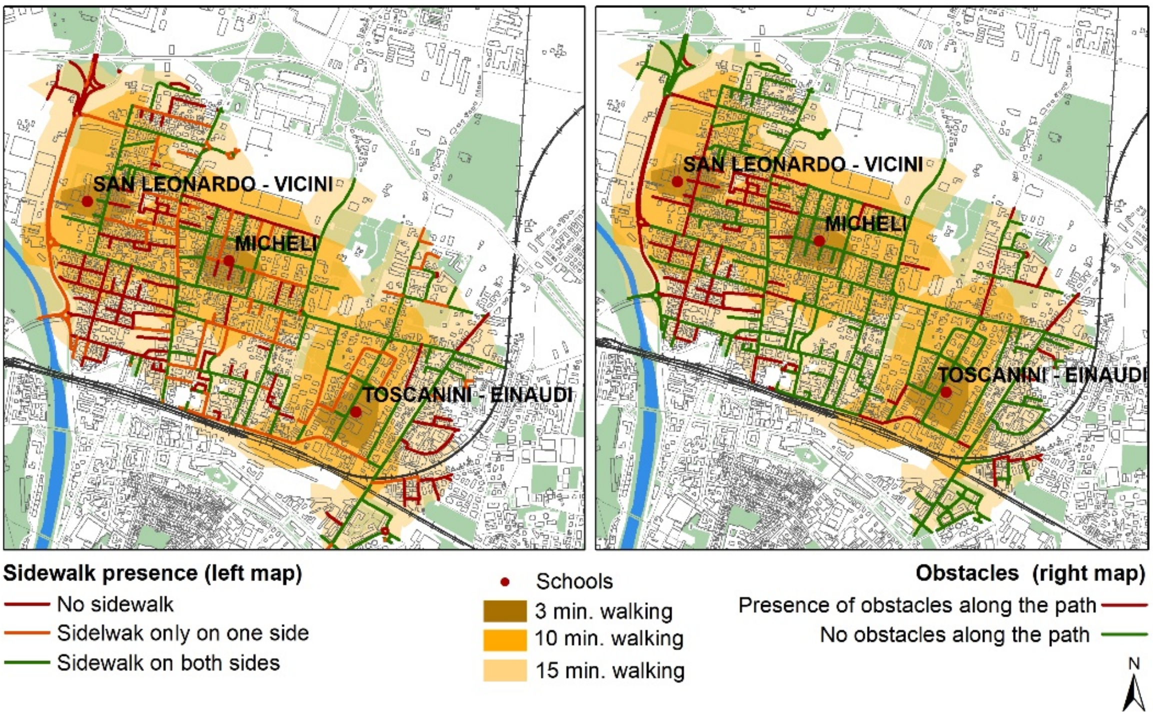


Fig.2 Examples of thematic maps for the inspected road segments within the 3-, 10- and 15-minute isochrone from some of the considered schools. Each road segment is coloured according to sidewalk presence (left) and obstacles (right)

Fig.2 shows just few of the possible thematic maps that could be developed with the collected data. The sidewalk provision is shown in Fig.2 on the left: there is a small number of green links with the sidewalk on both sides and this happens above all passed the immediate surroundings (3-minute isochrone) of the school. The presence of obstacles is graphically shown in the Fig.2 on the right: in the case of the San Leonardo - Vicini school, there is a greater presence of obstacles along the path. Then, the SWI was assessed for each road and pedestrian segments included in the 3-, 10- and 15-minutes catchment areas of the primary schools. Fig.3 shows the obtained SWIs for each segment around some of the analysed schools. It evidently emerges in the zoom (on the right) low SWI values associated with the links around the schools of Verdi and Vigatto. In fact, near these two schools, located in peripheral and rural areas of the city it is possible to highlight that the sidewalk is not always present. Afterwards, calculating the arithmetic mean of the SWIs associated with each road and pedestrian segment within the considered isochrones, it was possible to obtain an overall evaluation of the walkability for the 3-, 10- and 15-minutes walking catchment areas of analysed schools (Fig.4a and 4b).

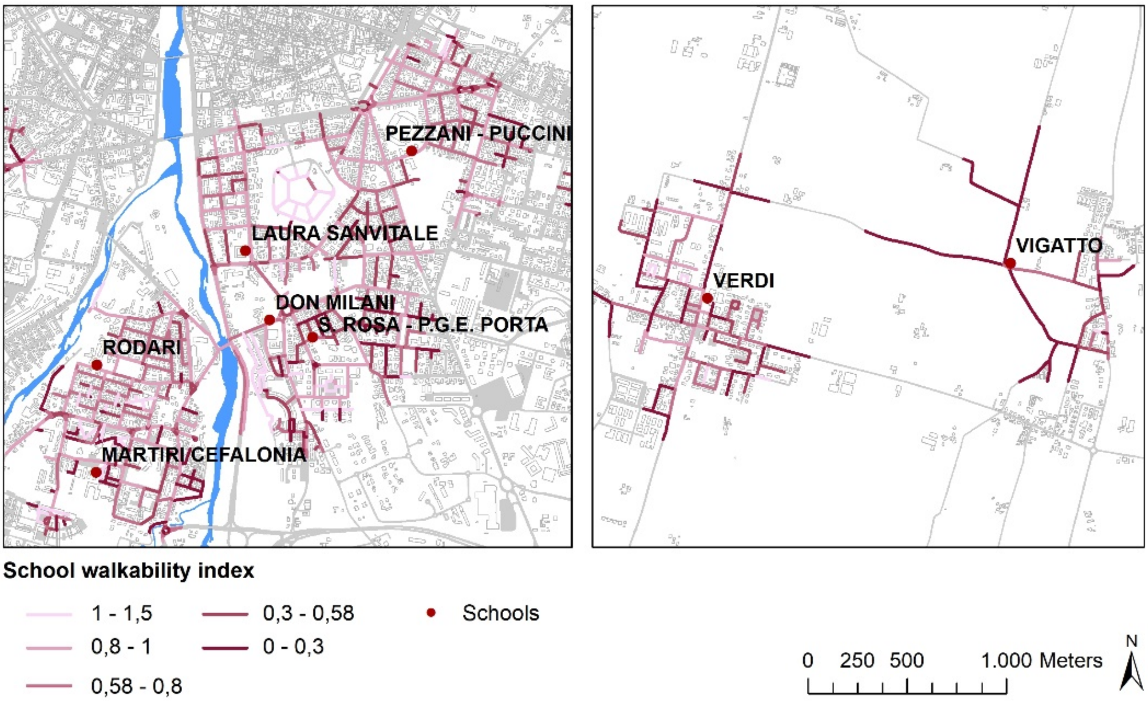


Fig.3 SWI applied to the road segments within 15 minutes walking from some of the analysed primary schools in Parma

A quantitative analysis of the obtained results was summarised in Tab.2, reporting the SWIs for all the analysed school sites, for each of the three isochrone levels considered. On average, the number of schools with a low average SWI value is equal to 38% for the 3- and 10-minute isochrones and it rises to 43% for the 15-minute isochrones. Carrying out a global assessment for the three levels of isochrones, there is an equal distribution between the schools with the worst and best average SWI, in both cases equal to 3 schools.

Then, punctually analysing some schools, it is possible to highlight that in some cases redevelopment interventions would be needed in the immediate vicinity (i.e. Laura SanVitale and Martiri Cefalonia schools); instead, in other cases within the 3-minute isochrone the walkability is good, but moving to 10 and 15 minutes of walking distance the value of the average SWI becomes critical, making walking to the school difficult both in terms of comfort and safety (Fig.5).

This happens, e.g., in the cases of the Anna Frank and Micheli schools, because the larger service areas (10- and 15-minute isochrone areas) either straddle a peri-urban zone or an obsolete residential area where pavements are not always present on streets, or these are not properly dimensioned.

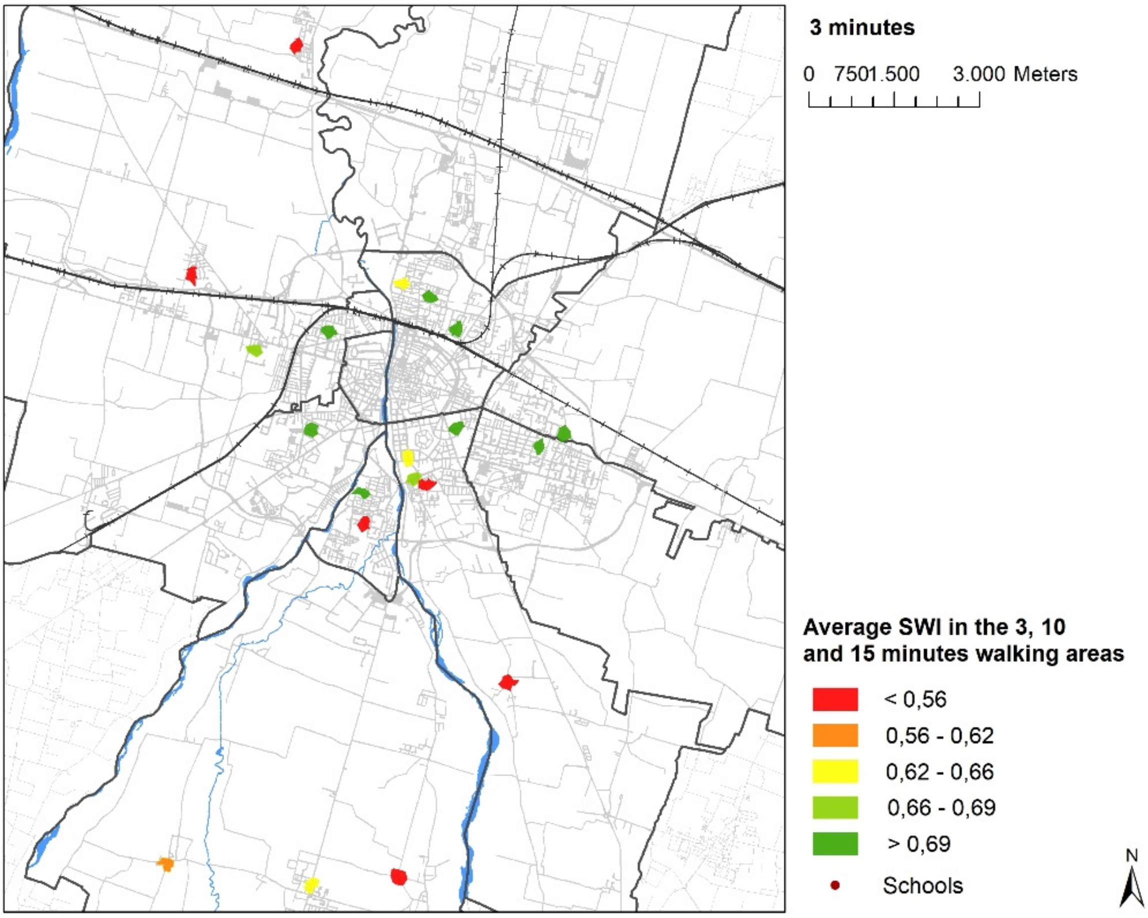


Fig.4a Average normalised SWI in the 3-minute walking catchment areas around the analysed primary schools

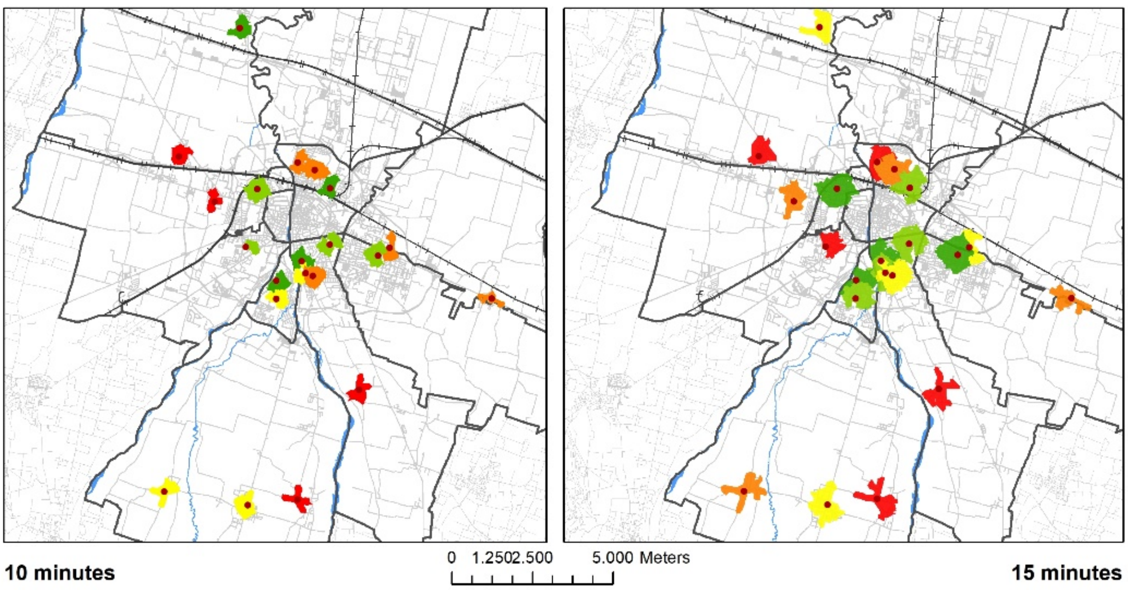


Fig.4b Average normalised SWI in the 10- (on the left) and 15- (on the right) minute walking catchment areas around the analysed primary schools

School name	Average SWI 3 minutes	Average SWI 10 minutes	Average SWI 15 minutes
ALBERTELLI	1.27	0.72	0.70
ANNA FRANK	0.69	0.54	0.59
BOTTEGO	0.72	0.60	0.64
BOZZANI	0.33	0.28	0.30
CAMPANINI	0.41	0.75	0.66
CARIGNANO	0.60	0.67	0.59
CORAZZA	0.74	0.73	0.56
DON MILANI	0.67	0.69	0.68
FOGNANO	0.49	0.42	0.44
LAURA SANVITALE	0.62	0.74	0.78
MARTIRI CEFALONIA	0.56	0.69	0.69
MICHELI	0.73	0.62	0.62
PEZZANI - PUCCINI	0.72	0.72	0.67
RACAGNI	0.78	0.72	0.70
RODARI	0.79	0.76	0.71
S. ROSA - P.G.E. PORTA	0.37	0.66	0.65
SAN LEONARDO - VICINI	0.62	0.58	0.52
TOSCANINI - EINAUDI	0.72	0.75	0.69
VERDI	0.65	0.68	0.63
VIGATTO	0.32	0.38	0.52
ZERBINI	0.27	0.60	0.60

Tab.2 Average SWI in the catchment areas of each analysed school

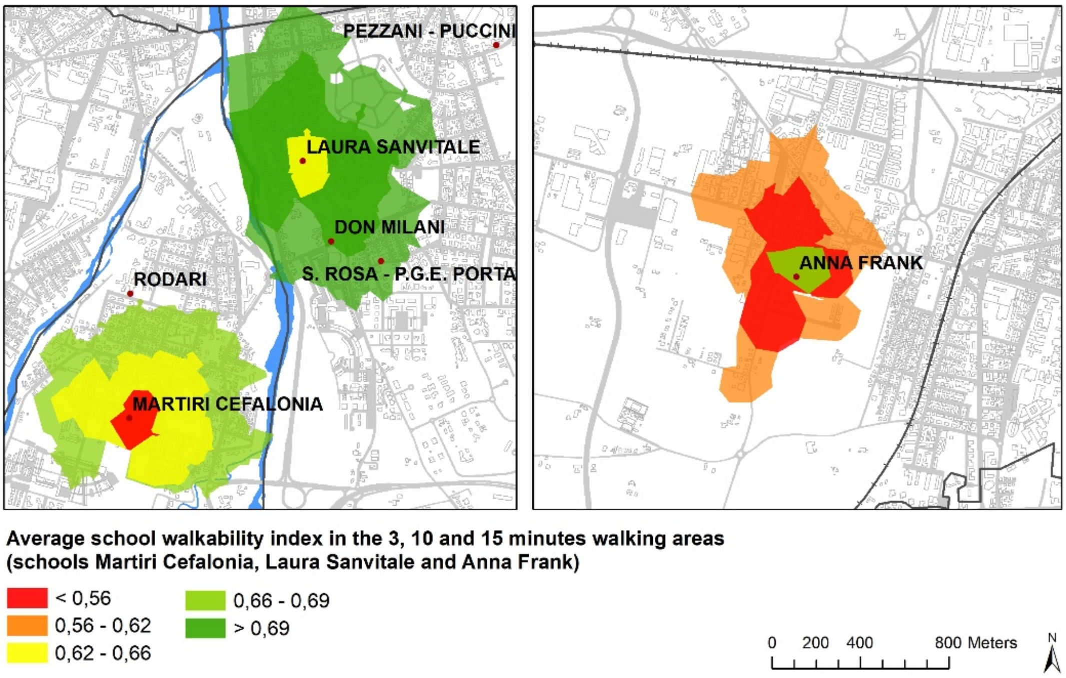


Fig.5 Average normalised SWI in the 3-, 10- and 15-minutes walking catchment areas around some of the analysed primary schools that presents different walkability levels in the different isochrones

4. Conclusions

As reported in the literature, school zones (often addressed as school streets or school squares) have positive impacts on children, families, and the environment in general. Their delimitation, in conjunction with road redesign (also through tactical urbanism) to solve walkability criticalities along the routes, could play a crucial role in boosting walking to schools. The proposed methodology provides an assessment of walking catchment areas around schools highlighting the most critical routes in terms of walkability index, where those kinds of interventions could be more successfully applied. Furthermore, the methodology could also allow the identification of punctual areas around schools where even smaller interventions can improve single walkability bottlenecks or obstacles (e.g. by removing single parking stalls and extending the sidewalk on the model of parklets (Campisi et al., 2022)). All these measures could boost the shift toward active mobility and respond to some of the challenges that contemporary cities are facing: i.a., environmental sustainability, energy transition, resilience, social inclusion and equity (Carpentieri et al., 2023; Carra et al., 2022; Costa & Delponte, 2024; Gargiulo et al., 2022; Papa et al., 2018; Spadaro et al., 2023; Tiboni et al., 2021; Tiboni & Rossetti, 2012; Tira et al., 2020).

The proposed methodology will be exploited, e.g. by considering how the length of each road segment could affect the overall walkability around the school. Further improvements could also involve some analysis of the perception of school pupils (e.g. through questionnaires or surveys), as also already partially done for some pilot primary schools in Parma (San Leonardo, Cocconi and Micheli schools) by the municipality, through the 'Gamification' experience developed in 2021 thanks to the URBACT project 'Thriving Streets'.

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Attributions

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Permanently temporary. Street experiments in the Torino Mobility Lab project

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Abstract

Street experiments introduce changes in the use, regulation or form of streets with the aim of triggering systemic shifts in urban mobility from motorized traffic to active travel and more livable public space. Generally intended to be temporary at implementation, street experiments may be repeated over time or even become permanent, depending on their success. This paper analyses four experimental road reallocation interventions that were implemented in August/December 2020 in the Italian city of Turin, as part of the *Torino Mobility Lab* project. These pedestrianizations were implemented in a temporary, experimental and low-cost way for four months, during which a monitoring activity was launched in order 1) to measure the use and the perception of the value of these temporary pedestrianizations in order to decide whether or not to make them permanent, and 2) to collect data on the ways they were used, as well as suggestions from their users for the design of the permanent versions of those that would have been confirmed. The paper analyses this monitoring/evaluation process and identifies some barriers and factors that can complicate and slow down the transition from temporary to permanent street reallocation.

Keywords

Street experiments; From temporary to permanent; Pedestrian areas.

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1. Street experiments

Streets fulfil two main functions. Firstly, they enable public life: they host social interactions related to fundamental urban functions, such as play, leisure, shopping and so on (Bocca, 2024; von Schönfeld & Bertolini, 2017). Secondly, they accommodate competing flows of various – motorized and non-motorized – transport means. In recent decades, the latter function has been prioritized in most urban areas at the expense of the former, in parallel with the establishment of the dominant paradigm of automobility (Gössling et al., 2016; Norton, 2015). However, especially in the past few years, two main crises stressed the urgency of rethinking urban streets. First, the necessity of mitigating climate change requires reducing car use and parking, so to promote a modal shift away from carbon-intensive to low-carbon modes of travel (Brand et al., 2021). Second, the Covid-19 pandemic highlighted the importance of freeing up outdoor public spaces for activities that are no longer feasible in restricted indoor spaces when social distancing is required (Abdelfattah et al., 2022), as well as the value of active travel for exercise (Nurse & Dunning, 2020).

As a consequence, an increasing number of cities are experimenting with street-space reallocations in favor of walking, cycling and public transport (D'Amico, 2023; Lahoorpoor et al., 2022). These "street experiments" use intentional, temporary changes in street functions, regulation and/or form, to explore systemic change in urban mobility, away from "streets for traffic" and towards "streets for people" (Bertolini, 2020). One of the recognized advantages of these experiments is that they allow testing new temporary, quick, low-cost solutions, assessing their results and impacts, and then deciding whether to promote these solutions in permanent versions. At the same time, some authors (see, for example, Bragaglia & Caruso, 2020) point out that street experiments can turn out to be a way out for administrations and local leaders to continue promoting neoliberal policies. Because of this ambivalence, it is important to assess the results of temporary street experiments through a public transparent process, particularly when they are supposed to later become permanent if successful (Campisi et al., 2020; Sadik-Khan & Solomonow, 2017).

Till now, in the academic literature on street experiments, particular attention has been focused on pedestrianizations, in relation to both their impacts on mobility patterns and their "stationary" uses, such as playing and socializing. However, these studies generally examine the effectiveness of pedestrianized streets in their permanent and structural version (which is normally provided with street furniture, trees, benches etc.; see, for instance, Campisi et al., 2020; Davis, 2020; Mehta & Bosson, 2021); on the contrary, poor attention is generally paid in the literature to monitoring and evaluating their temporary versions.

In response, this paper aims to critically analyze the monitoring and evaluation processes of *Torino Mobility Lab* (henceforth, TML), an experimental project aimed at promoting active mobility in the San Salvario neighbourhood of Turin, Italy. In the framework of this project, four portions of streets in the neighbourhood were temporary and "experimentally" pedestrianized (Section 2). During four months, the use of these new public spaces was monitored and evaluated to decide whether to confirm the pedestrianization or not (Section 3), as well as to obtain suggestions and indications for designing the permanent versions of these street portions (Section 4). The analysis of this process offers an overview of some barriers and factors that can complicate and slow down the transition from temporary to permanent street redesign.

2. The *Torino Mobility Lab* project

Turin is the capital of Piedmont region, in the North-Western part of Italy. It is the fourth most populated Italian city, with around 867,000 inhabitants in the city and 1.8 million in the functional urban area. The city is highly car-dependent, to some extent because of the dominant role historically played in Turin by the car company FIAT: the car ownership rate exceeds 650 cars for every 1,000 inhabitants (one of the highest in Europe); the modal share of private motorized mobility is 39%, compared to 24% of public transport and 3% of cycling (EMTA, 2021). Walking has a modal share of 34%, with a high level of walkability thanks to the continuous provision of pavements along nearly the whole street network and the presence of pedestrian areas (0,62 sqm per inhabitant). In the last twenty years, these areas were expanded in the historical core of the city, in particular around monuments and museums, while they are still quite scattered and discontinuous in the outskirts.

In 2016, the Italian Ministry of the Environment issued a call for funding[1], aimed at promoting walking and cycling and reducing traffic, air pollution, and vehicle parking near schools and workplaces in Italian cities. The City of Turin responded to this call by presenting a project, titled *Torino Mobility Lab* (TML), which focused all its measures and economic resources in one of the city's neighbourhoods, with the aim to test an approach that, in case of success, could be progressively replicated in the other parts of the city. The chosen area was San Salvario, a semi-central, densely populated neighbourhood located at the edge of the historic city centre. San Salvario was selected for its structure (a dense and mixed neighbourhood developed on a regular grid of streets, suitable for adopting a superblock-like approach) and for the presence of a large number of local associations, very inclined to sustainable mobility issues.

The TML initially mainly focused on promoting cycling, through a mix of hard and soft measures. However, after the pandemic outbreak in 2020, the City shifted this focus to pedestrianizing 11 portions of the neighbourhood's streets, in order to offer local schools and associations new public spaces, free from cars, where to perform outdoors those activities that could no longer be carried out indoors due to social distancing. Seven of these interventions merely widened the existing pavements. In the other four cases (Fig.1), entire portions of streets – each located near a school or an association – were closed to cars in August/September 2020, in a temporal, low-cost form (by simply placing planters at their extremes, to prevent car traffic). The City defined these closures as an "experiment", supposed to last four months until 31st December 2020, when they should have been re-assessed on whether to confirm them in a definitive form.

Fig.1 The four pedestrianised areas in the San Salvario neighbourhood (in green)

The four temporary pedestrianized areas were:

- *Corso Marconi*. It is the oldest tree-lined street in Turin, traced in the XVII century to connect the San Salvario church and the Castello del Valentino (which now hosts the academic departments of Architecture and Spatial Planning). It has a boulevard structure, with a central large lane and two minor side lanes separated from the central one by a line of trees. Only a portion (240 mt) of the central lane

[1] "Experimental national program for sustainable home-school and home-work mobility". Retrieved from: https://www.mase.gov.it/sites/default/files/archivio/allegati/mobilita_sostenibile/dm_28_07_2016_208_mobilita_programma_sperimentale.pdf

was closed to cars using planters where a perpendicular street crosses it; the lateral lanes are still open to cars. One of the four blocks lining the street is occupied by a school complex, which includes a kindergarten, a primary and a junior-high school. Two of the other three blocks accommodate on their ground floor 13 shops; three of them (a cafè, a restaurant and an ice cream shop) installed dehors under the trees. About twenty wooden benches have been placed in the pedestrianized area;

- *Via Principe Tommaso*, 66 meters long, corresponding to one block, with pavements all along. It is adjacent to a nursery/kindergarten; a restaurant, some shops (a hairdresser, a clothes shop, a furniture atelier etc.) and a cultural club are located along the street. Because of a private driveway, the street was closed to cut-through traffic placing planters at its two extremes spaced so as to allow a car to reach the driveway;
- *Via Lombroso*, 60 meters long, corresponding to one block, with pavement all along. At one of its corners is located the headquarter of an association promoting cross-cultural engagement (ASAI), which had been organizing outdoor activities for children and teenagers on the street's pavements since a long time; the rest of the street is full of shops (a café/bike shop, an atelier for furniture refurbishing, a greengrocer, a hairdresser). The pedestrian area has been marked using two planters at one extreme and another couple just after a driveway, so to allow cars to reach it more easily. After the street was closed, the café/bike shop equipped itself with a dehors; the ASAI also placed some removable equipment for its outdoor activities and commissioned a painting on the surface of the street and on the two central planters;
- *Via Morgari*, 42 meters long, corresponding to about half a block, with pavement all along. It is adjacent to a Catholic church and connected through a small garden to the so-called 'Neighborhood house', a local cultural center. The pedestrianized portion of the street was closed by a couple of planters at its two extremes.

3. Assessing temporary pedestrianizations

The 2016 Ministerial call for funding required that each proposed project could be funded only if it included "activities aimed at measuring the actual degree of success of the actions implemented and the actual use of the services activated and infrastructures implemented, the assessment of the satisfaction of the end users, the measurement of the data required for the ex-post evaluation of environmental benefits". Therefore, TML devoted a part of its total budget to monitoring the impacts of its measures in terms of change of modal split (with particular attention to the share of bike trips) before and after their implementation. At the end of 2019, when the implementation phase of the project started, this part of the budget was used to fund a third party to perform the monitoring activity for one year (from 3rd December 2019 to 30th November 2020), as well as the communication and participation tasks of the project. The monitoring activity was granted to a temporary joint venture (henceforth, ATI – *Associazione temporanea d'imprese*) involving four local associations.

The ATI began its activity by carrying out a survey in the first months of 2020, aimed at assessing the current modal split, residents' mobility needs and the first impacts of pandemic lockdowns on local journeys in San Salvario. When the City modified the overall TML project by giving priority to the experimental pedestrianizations, the ATI accordingly adapted its monitoring activity with a two-fold aim of: 1) measuring the use and the perceptions of the temporary pedestrianizations in order to decide whether or not to make them permanent, and 2) collecting data on the ways in which they were used, as well as suggestions from their users for the design of the permanent versions of those that would have been confirmed.

After the beginning of the experimentation in August 2020, three types of monitoring activities were launched. First, the ATI assessed the use of the pedestrianized areas by adopting two methods developed by Gehl and Svarre (2013). The first method was the so-called "People moving count", through which the number of people (per minute) walking through each of the four pedestrianized streets was measured. Data were collected over

10 minutes on three different days (one between Monday and Thursday, one between Friday and Saturday, and one on Sunday) and in three different time slots (between 8:00 and 9:00, between 18:00 and 19:00, between 22:00 and 23:00). The second method was the "Stationery activity mapping", which detected both how many people were spending time in the analyzed area and which activities (and where) they were performing. These data were collected over 30 minutes; their temporal distribution (days and time slots) had to respect the same criteria used for the people moving count tool. The two tools were applied by 9 times (3 in the morning, 3 in the afternoon, and 3 in the evening) to each of the 4 pedestrianized areas in each of 3 monitoring sessions (September/October 2020, November 2020 and December 2020).
Second, the ATI carried out three surveys in October 2020 to detect local perceptions of the new car-free areas. A questionnaire (both online and in printed version) was submitted to the neighbourhood's residents, asking them whether they believed the pedestrianizations had improved the livability of the four areas and why (or why not). A second questionnaire was submitted to the parents of the students attending the school in front of Marconi Avenue, to investigate whether the pedestrianization had improved the safety levels when students entered/left the school, and how they used the car-free space. As regards the shopkeepers working along the pedestrianized streets, their perceptions were detected through semi-structured interviews.
Finally, three workshops were organized in November 2020 to gather suggestions by 15 stakeholders (selected to represent local associations, residents and shopkeepers) for redesigning in permanent structural terms two of the four pedestrian areas.
The analysis of this monitoring/evaluation process highlighted some critical issues (Vitale Brovarone et al., 2023). The first was related to the content of the experiment. The pedestrianized street portions that were tested in the second half of 2020 were merely implemented by placing planters at their extremes to prevent car traffic, without any redesign of street furniture. They were quite different from the project of the structurally re-arranged streets that were supposed to be permanently realized at the end of the experimentation by placing furniture, benches and so on. It is likely that the uses of the temporary versions of the pedestrianizations monitored through Gehl's methodology were quite different from the ones that will be performed in their permanent versions.
This emerged clearly during the monitoring phase, as the ATI reported: "*There is little point in having pedestrianized stretches of street, leaving them unchanged, without any furniture or greenery or characterization, albeit temporary, which would have allowed citizens to experience and appreciate a different use of public space. Obviously, this perception, which has greatly affected the current evaluations, may change if adequate redevelopment work is carried out. It has to be said, however, that one of the problems noted in the current experimentation has been that the pedestrian spaces […] could not be fully evaluated as effective spaces returned to citizens, usable for social or aggregative uses: they were perceived as 'empty and unconnected spaces*" [ATI, 2020, p. 8, translation by the authors].
This could explain the prevailing negative ratings from the interviews carried out in October 2020 among the residents: only 25% to 40% (depending on the area considered) declared that the pedestrianizations had improved the livability of the closed streets.
A second problem was related to the benchmark for assessing the confirmation of the experimentations. The City did not identify any threshold value neither for the two Gehl's indicators nor for the percentage of interviewees that – in the above-mentioned survey in October 2020 – stated to be satisfied with the experimentation. Without these benchmarks, it was not clear how and why the City decided in November 2020 to confirm three experimentations and conversely to remove the one in Morgari Street. It is true that this latter case recorded the most negative values for all the indicators, but they were not so significantly worse compared to the others. Moreover, also for Principe Tommaso and Lombroso Streets and for Marconi Avenue less than 40% of the interviewees answered that the pedestrianizations had improved their livability. So, when in November 2020 the City presented the projects for the permanent re-organization of three streets and for re-

opening Morgari Street, most local stakeholders were surprised, as they could not understand the motivation behind this decision.

Finally, some concerns were raised regarding the scheduling of the monitoring (August-December 2020). The experimentations started in August, the peak summer holiday season in Italy when most people are away from home: this was locally interpreted as a way to introduce these experiments in a top-down approach, without attracting too much attention from the residents. The surveys to residents, parents of the students of the schools and shopkeepers were held in October, long before the end of the experimentation. Moreover, the decision about the success of the experiments was expected to be taken in December, one of the coldest months of the year (hence, in a moment not favourable to the use of open public spaces); in reality, it was taken in November, one month before the established end of the experiment, also in this case without a clear reason.

4. Moving from temporary to permanent street re-designing

More than six years after obtaining the funding and nearly three years after the decision about confirming (or not) the four pedestrianizations, in November 2023 the TML is finally close to completing its transition from temporary to permanent

The experimental nature of the TML - which was meant to be implemented first with temporary pedestrianizations and subsequently with permanent redesign -, and the urgent need to respond to Covid-19 by reallocating public space, allowed for a rather fast closure to vehicular traffic. However, a long time passed after that step. There are many reasons for the extended time frame for the implementation of the project, and in particular for the transition from simple closure to vehicular traffic to permanent reconfiguration of the pedestrianized streets. These include complications related to the pandemic, the slow bureaucratic process for implementing public interventions, the multiplicity of stakeholders involved etc. But also, and perhaps most importantly, other issues that were less evident at first glance proved to be key factors. These include the multiplicity of instances regarding the use of road space, the presence of conflicts of various kinds, the political implications of the initiative, the complicated governance of the process and the absence of clear leadership (Vitale Brovarone et al., 2023; Verlinghieri et al., 2023).

Undoubtedly, the bureaucratic process of moving to permanent redesign is far more complex than simply closing it to vehicular traffic. However, the analysis of the project development process reveals timeframes that cannot be ascribed only to bureaucratic difficulties. In particular, between the fall of 2020 and the end of 2022, no substantial changes in the configuration of the pedestrianized areas took place. Work on the permanent redesign started in late 2022 and is being completed in Autumn 2023 (Fig.2).

Fig.2 Via Lombroso in the temporary (on the left) and permanent (on the right) version

The final plans for the permanent redesign of the pedestrianized streets have undergone several changes. Given the objectives of the monitoring activities, one might expect that for the final design, the municipality would have taken into account the suggestions and instances that emerged during the monitoring activities. However, this was not the case, and the redesign in permanent mode was rather the result of mediation between the demands of the institutionally most powerful actors in terms of influence and control on decision-making. In particular, although citizens, schools, and local associations were initially involved in the formulation of redesign proposals, somehow giving the idea that it was a co-design process, the final redesign was the outcome of the interaction between the Municipality and the Superintendence of Archaeology, Fine Arts and Landscape[2]. The former as the beneficiary of the funds and responsible for urban planning and mobility in the city, the latter as responsible for authorizing interventions in contexts that are constrained or protected for their architectural, historical-artistic and landscape value.

Much of the pedestrianized streets in San Salvario are in fact subject to protection under the Cultural Heritage and Landscape Code (D.Lgs. 42/2004). In addition, Corso Marconi is subject to constraint under a regional decree (D.D.R. n. 587/2014). For this reason, while in the initial stages of the project the Superintendence was not involved to a large extent, it played a leading role in the permanent redesign phase, particularly for Corso Marconi but also for the other streets. The Superintendence's requests concerned in particular the protection of scenic views, which affect Corso Marconi as a historic tree-lined boulevard attested to the Valentino Castle on one side and the church of San Salvario on the other, but also some other streets subject to pedestrianization. In addition, the Superintendence required uniformity of design choices in all pedestrianizations, while the City Council had initially opted for diversification. Finally, it required design choices that favoured symmetry, axiality, and the use of low-key colouring that matched the surroundings[3]. The Municipality, on the other hand, had initially envisioned, partly as a result of consultation with schools and associations in the area, large colourful patterns in the style of tactical urbanism, and curved seating.

Another factor that caused the project to be changed from the initial ideas was the budget, which turned out to be insufficient to realize what was planned. As a result, the Municipality scaled down the size of the areas to be coloured[4], limiting them to parking spaces where benches or bicycle racks will be placed. Also, while it was planned to raise the street level to the height of the sidewalk, to give a sense of continuity to the pedestrian area[5], in some cases the raising did not extend for the entire pedestrian area, maintaining the separation of levels where there were driveway accesses. This was both for budget reasons and to highlight the fact that the right-of-way for residents remained in that section (Fig.3).

Fig.3 Principe Tommaso Street in the temporary (on the left) and permanent (on the right) version

2 The Superintendence is a territorial body of the Italian Ministry of Cultural Heritage and Activities. It is responsible for ensuring in the territory of the city and metropolitan city the protection of archaeological, architectural and historical-artistic heritage and landscape.

3 Also in line with the municipal colour plan.

4 Not a simple painting but the laying of a coloured film in material that provides longer life and lower maintenance costs, in spite of a significantly higher cost of implementation.

5 The monitoring had noted the persistence of pedestrian flows on sidewalks given the perception of the street still as something separate from the sidewalk (Verlinghieri et al., 2023).

5. Conclusion

This paper analyzed the transition from temporary to permanent pedestrianization of four street portions in San Salvario, as part of the TML project. Granted ministerial funds in 2017 and launched in 2019, the TML is just now (November 2023) being completed. In August 2020 the road space was experimentally closed to car traffic, in December 2020 the pedestrianizations were confirmed and announced to become permanent. Making them permanent included their redesign to improve their pleasantness and usability for walking, playing, resting etc.

As required by the ministerial call, the project included a phase of monitoring and evaluation of the pedestrianizations. This activity was announced as preparatory to the decision regarding the confirmation of the interventions and their redesign into a permanent version. The monitoring, entrusted by the Municipality to a grouping of local associations, took place between December 2019 and November 2020 and included, despite the advent of Covid, several opportunities for exchange with the local community to detect critical issues, opportunities, and ideas for permanent pedestrianization.

The transition from the temporary to the permanent phase has been a long one. The final results seem to take into account the outcomes of the monitoring to a small extent. Rather, the final version, the design of which has undergone several modifications, is the outcome of mediation and dialogue among the institutionally most influential actors in the decision-making process, making monitoring and consultation with local stakeholders a mere fulfilment of the call’s requirement.

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Image Sources

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The exploration of tactical urbanism as a strategy for adapting to climate change. The "SpaziAttivi" program in the city of Brescia

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Abstract

Lately, conventional urban planning strategies have encountered a new and often opposing force known as Tactical Urbanism, which has gained widespread prominence. This movement represents an approach to addressing issues at the neighborhood level, intervening in public spaces through citizen involvement and implementing temporary, cost-effective solutions. The Municipality of Brescia is actively exploring this innovative approach through the "SpaziAttivi" project, a component of the Climate Transition Strategy approved in 2021. This paper aims to elucidate why tactical urbanism has been chosen as the preferred method to enhance understanding, awareness, and the adoption of a collaborative approach to addressing climate change adaptation and mitigation issues. Specifically, the paper seeks to delineate the methodological process employed in selecting areas for tactical urbanism experiments, considering other successful participatory processes in Tactical Urbanism. The selection process ultimately leading to the decision to intervene in two areas, a significant reduction from the initial 56 proposals put forth by the citizens.

Keywords
Tactical urbanism; Climate change adaptation; Participatory design.

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1. Introduction

Thanks to integration policies developed since the 1950s, harmonizing vehicular and pedestrian traffic, pedestrian environments have experienced a resurgence in popularity in recent decades (Yassin, 2019). Urban planners now recognize pedestrian spaces as integral components of urban planning, offering environmental, cultural, economic, and social benefits (Blaga, 2013). The emergence of COVID-19 has profoundly reshaped our cities, prompting significant shifts in people's behavior. With restrictions in place, individuals have found themselves spending more time engaged in activities like walking and cycling, as traditional entertainment options became limited. In fact, slow individual transport modes (walking and cycling) have proven consistent with the need for social distancing and, more generally, with the need to improve people's health and well-being (Fasolino et al., 2020). This change in habits has underscored the necessity for a reevaluation of pedestrian and cycling infrastructure, as well as the utilization of open spaces within cities (Zecca et al., 2020). In particular, the goals of creating walkable environments and improving the walkability of urban areas span multiple disciplinary fields including urban planning, public health and climate change issues (D'Amico, 2023). Traditional planning strategies, rooted in rational methods that assumed confined spaces and linear processes for simplified and optimized interventions (Wohl, 2018), regarded the territory as a neutral platform without considering its social component, leading to project failures. Consequently, becomes more evident that there are significant correlation between the geometric attributes of urban spaces and their perception by users, providing valuable insights for designing public spaces tailored to the encountered needs (Boglietti & Tiboni, 2021). Urban planning has shifted towards more reflexive, critical, and inclusive positions, moving away from a preference for physical interventions to a focus on understanding and influencing the procedural aspects of change (Wohl, 2018).

In the literature, temporary urban interventions emerge as a potential tool for altering traditional attitudes towards spaces and behavior, fostering long-term change (Bishop & Williams, 2012; Tonkiss, 2013) introduce Tactical Urbanism as a new transformative approach, contrasting with conventional urbanism. Tactical Urbanism emphasizes an open and iterative process, efficient resource utilization, and the latent potential in social interaction. Citizens leverage tactical urbanism to draw attention to perceived deficiencies in policies and physical design, while municipal authorities, organizations, and project developers employ it to expand public involvement, test plan aspects early and often, and expedite implementation, facilitating the creation of vibrant spaces (Lydon & Garcia, 2015).

Tactical urban design interventions reclaim urban space and contribute to temperature reduction in cities, such as through pedestrianizing vehicular roads and utilizing materials that enhance sunlight reflectivity.

The Municipality of Brescia incorporates tactical urban planning interventions into the Climate Transition Strategy (CTS) (Comune di Brescia con il contributo di Fondazione Cariplo, n.d.). Approved in 2021, the CTS encompasses 30 actions for adaptation, mitigation, participation, and community involvement, aligning with medium- and long-term planning integrated with the Municipality's general and sectoral planning tools. The goal is to transform the city into an oasis, a sponge, and a people-centric urban space. Involvement and participation actions play a pivotal role in building resilient communities, increasing climate change awareness by addressing territory needs and participating in interventions to enhance the urban microclimate. Establishment of people and climate-oriented cities entails two fundamental processes within physical contexts: the revitalization of existing urban areas, with a focus on enhancing public services for each urban unit, and the strategic planning of their accessibility. Consequently, there exists a robust correlation between the objectives of people and climate-oriented initiatives and temporal and proximity perspectives (Carra et al., 2022). The "SpaziAttivi" project, as an organized participatory process, seeks to address climate mitigation and adaptation issues through a socially sensitive approach.

This paper aims to outline the methodological process for selecting areas to experiment with tactical urbanism. Through rapid and experimental implementations, spaces can be redesigned to promote climate adaptation and pedestrian environments, eventually leading to shared permanent realizations with the community. The article seeks to illustrate the "SpaziAttivi" participatory pathway, comparing it with other experiments in Milan and Bologna discussing the methodological approach and strengths and weaknesses for the benefit of other urban realities undertaking a similar path.

The structure of the paper is as follows: Section 2 presents virtuous examples of tactical urbanism in Milan and Bologna. Section 3 outlines the "Un Filo Naturale" project and the Climate Transition Strategy. Section 4 describes the methodology used to identify areas for tactical urbanism. Section 5 presents the results applied to the city of Brescia. Section 6 compares the "SpaziAttivi" project methodology with analyzed examples, concluding the work and discussing future developments.

2. Virtuous examples of tactical urbanism

To the best of the authors' knowledge, notable instances of successful experimentation with tactical urban planning, facilitated through collaboration with public administration, include the "Piazze Aperte" project in Milan and the establishment of school squares in Bologna. These examples were presented to participants during workshops as part of the participatory process within the "SpaziAttivi" project. The intention was to provide participants with insights into the project's objectives and methodology.

2.1 Piazze Aperte

"Piazze Aperte" is a collaborative initiative led by the Municipality of Milan in partnership with the Agenzia Mobilità Ambiente Territorio (AMAT), Bloomberg Associates, and Global Designing Cities Initiatives. The project's primary objective is to enhance public spaces as central meeting points within neighborhoods, expanding pedestrian areas and promoting sustainable forms of mobility to enhance both environmental conditions and the overall quality of life in the city (Comune di Milano, AMAT - Agenzia Mobilità Ambiente Territorio in collaborazione con Bloomberg Associates e Global Designing Cities Initiative, n.d.).

The initiative seeks to reposition public spaces at the heart of neighborhoods, transforming squares into vibrant community hubs rather than mere parking lots or transit zones. By returning these spaces to the residents, the project aims to reinstate the true essence of a "square" as a place for local interactions. Furthermore, "Piazze Aperte" represents a shift in how the municipality collaborates with city districts, fostering stronger relationships with residents who actively participate in the design process and the creation of new spaces.

The pilot projects in Piazza Dergano and Piazza Angilberto were initiated by Bloomberg Associates. Through engagement with stakeholders, these projects identified a set of initial squares, developed specific plans, and collaborated with Milan City Council departments to establish the first new squares in 2018. Throughout the temporary installations, the studio facilitated the city's assessment and monitoring of each area's impact, gathering feedback from citizens and analyzing behaviors in public squares. These analyses contribute to the eventual transformation of these spaces from temporary to permanent. By 2019, the program expanded to include ten sites across the city, reclaiming 100,000 square meters of public space, with plans for additional squares in the future.

Building on the success of the initial plaza launches, Bloomberg Associates, in conjunction with the mayor, initiated a public call for recommendations for new plazas starting in 2020. The goal is to bring lively public plazas to every corner of the city. The "Piazze Aperte" project received 65 proposals from private individuals, associations, and schools, resulting in the creation of 22 open squares (Fig.1).

2.2 School squares in Bologna

In the Municipality of Bologna, the inaugural experimental initiative of school squares was implemented in the Navile district through collaboration among the Municipality of Bologna, the Navile District, and the Fondazione

Innovazione Urbana (FIU). This project was conducted in partnership with the Politecnico di Milano and the University of Westminster as part of the European research project EX-TRA (Experimenting with City Streets to Transform Urban Mobility). Notably, the project aligns with the Plan for Emergency Pedestrianism, which seeks to explore new solutions for outdoor public spaces to address the challenges faced by individuals during the pandemic.

Fig.1 Proposals for the "Piazze Aperte" project

The primary focus of the Plan is to intervene in underutilized street spaces, transforming them into appealing and communal public areas, particularly catering to families, children, young people, and locations near schools. The interventions involve experimenting with alternative ways of utilizing public space through temporary arrangements that allow for diverse uses to maximize the space's potential.

The key objectives include:

- increase the spread of neighborhoods public spaces;
- create comfortable and balanced spaces using innovative and creative street furniture;
- create new space to be used for recreational, sports and cultural functions of proximity.

The selected intervention area is Via Procaccini near the Testoni-Fioravanti schools, identified by FIU in collaboration with the Municipality's Urban Planning Sector. The installation aimed to experiment with a new temporary pedestrian space to enhance students' autonomy and safety during their journeys between home and school, while also providing new spaces for meetings and waiting (Comune di Bologna e FIU, Fondazione Innovazione Urbana, n.d.). FIU led the architectural design, incorporating various elements such as colored paint on the ground, street furniture like racks, semi-circular benches, games drawn on the ground, ground lettering, benches, ball and semi-sphere concrete seats, and wooden tubs containing medicinal and ornamental plants. Notably, student involvement from the Testoni-Fioravanti middle school in defining games, ground inscriptions, and project signs added a unique and valuable dimension to the architectural design process. The

intervention spanned approximately 12 months, during which observation and monitoring activities yielded positive results in terms of space utilization and acceptance by users and residents.
Building on these initial tactical experiments, Bologna has embarked on five additional interventions to enhance the city's livability, starting with school squares (Fig.2).

3. Climate Transition Strategy

The "Call for Ideas Climate Strategy" has been annually published since 2019 by the Cariplo Foundation under the "F2C - Cariplo Foundation for Climate" project, which focuses on policies combatting climate change. The primary objective of this initiative is to endorse projects addressing both mitigation and adaptation to climate change through strategic and policy measures at the local level. In 2020, the city of Brescia participated in the call (resolution 315/2020) by presenting the project "Un Filo Naturale - A community participating to transform the challenge of climate change into opportunities." The development of this project occurred concurrently with the establishment of the Climate Transition Strategy (CTS) of Brescia, officially approved a year later (resolution 52/2021).

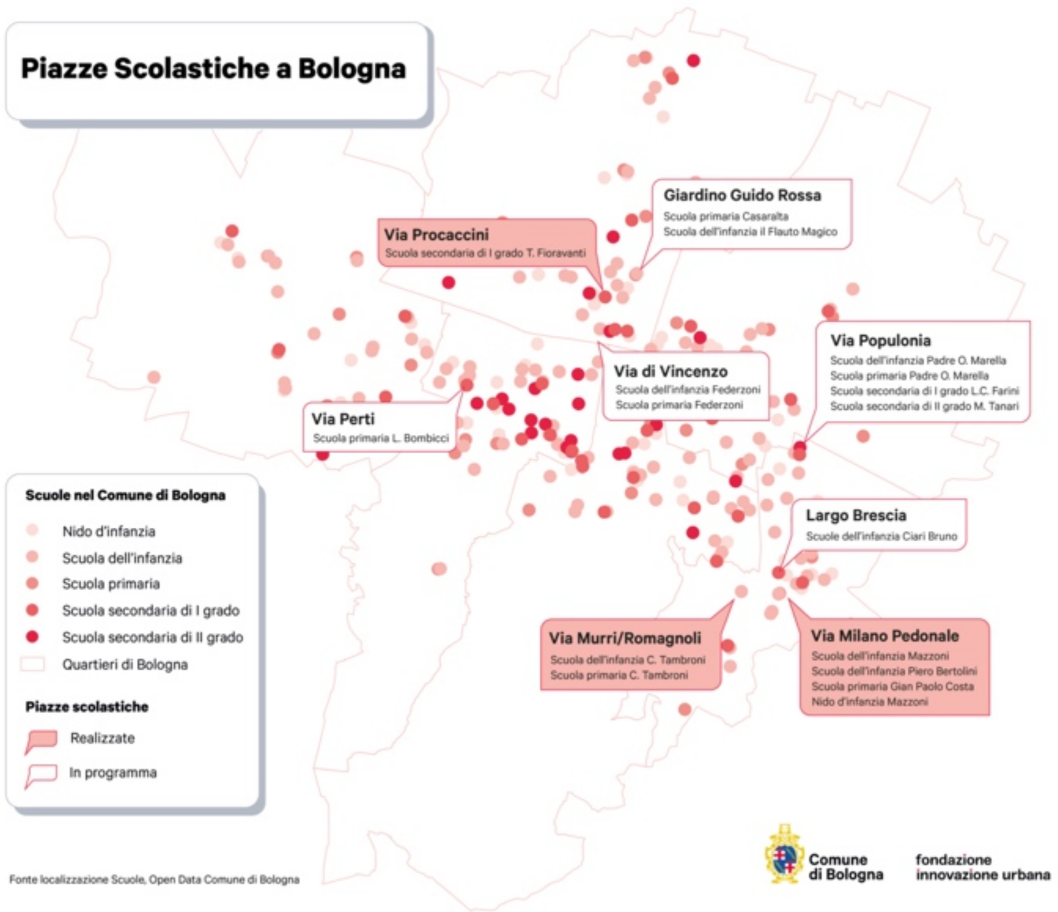

Fig.2 Proposals for the School squares in Bologna

"Un Filo Naturale" encompasses the formulation of 30 actions related to adaptation, mitigation, community participation, and engagement. This initiative unfolds over a medium to long-term timeline and integrates seamlessly with the overarching planning tools of the municipality, both general and sectoral. The overarching goal of "A Natural Thread" is to curtail emissions of climate-altering gases, refine the management of risks and criticalities, boost natural capital, and enhance resilient capacities. The project, with its 30 proposed actions, spans adaptation, mitigation, community participation, and engagement, all aligned with a medium to long-term plan that complements and dovetails with the comprehensive planning and programmatic tools of the municipality.

This comprehensive project encompasses a range of actions related to adaptation, mitigation, participation, and community engagement. While some of these actions are slated for the next five years, others align with a longer-term vision, all geared towards combating escalating temperatures, addressing heatwaves, and mitigating the impacts of extreme weather events. The overarching objective of the administration is to construct a territorial system characterized by continuous and progressive efforts to reduce emissions of climate-altering gases and enhance resilience through the ongoing improvement of risk management.

The CTS aims to fortify the city against climate change, adhering to models that embrace the concept of:

- OASIS CITY: Creating shaded and cool areas, infusing nature into urban spaces to enhance the well-being of residents and ameliorate the urban microclimate;
- SPONGE CITY: Facilitating the return of space to water and enhancing permeability to the earth, allowing for sustainable coexistence;
- CITIES FOR PEOPLE: Crafting even more livable spaces where the rights to health, communal interaction, and inclusion are safeguarded.

Integral to the success of the initiative are actions that encourage engagement and participation. These actions play a pivotal role in cultivating resilient communities. By focusing on the needs of the local territory, they not only increase awareness of climate change issues but also actively involve community members in the design of interventions aimed at improving the urban microclimate.

Within the broader framework of "Un Filo Naturale," the "SpaziAttivi" project takes center stage as a participatory process orchestrated by Urban Center Brescia. This initiative seeks to actively engage neighborhood councils, city associations, and citizens in the regeneration of urban spaces, placing the local community at the heart of the revitalization efforts.

4. Methodology

The "SpaziAttivi" project envisions the transformation of selected areas through citizen engagement in participatory design processes. In this approach, stakeholders actively participate in the design process to ensure that the final outcome aligns with their needs, fostering a stronger sense of community belonging. Tactical urbanism, originating as a grassroots initiative spontaneously promoted by citizens, has evolved into a tool embraced by local administrations.

The participatory approach plays a pivotal role in addressing the climate crisis, extending beyond technical and environmental solutions to promote social resilience. Citizen involvement not only raises awareness about climate change but also strengthens the community through various social initiatives, cultivating a shared sense of belonging to public spaces and, more broadly, a commitment to the well-being of the common good.

Within the "Spazi Attivi" project, small-scale urban transformation projects focused on climate resilience serve as catalysts for broader community change. The active participation of citizens in the transformation, care, and management of public spaces is the driving force behind this process. A participatory preparatory phase ensures that residents are well-informed about the project's benefits, actively engaging them in the initiative (Fassi in Orizzontale+atto, 2020). As a result, public spaces become shared assets, reinforcing a sense of belonging among those who actively contributed to the design process.

The "SpaziAttivi" project unfolds in various phases where participants, employing action research processes, identify, select, study, and propose climate adaptation and mitigation interventions for specific areas. The participatory process, initiated through meetings conducted between May and June 2023, identified unused, underutilized, or problematic public spaces. These areas are slated for transformation into active spaces through urban redevelopment, emphasizing both climate and social resilience. Workshops involving the community yielded 56 proposals, and a meticulous analysis process was employed to select the most suitable areas for participatory design. Despite the intricacy of handling numerous valuable proposals, this process was essential in identifying the two areas most conducive to accommodating planned activities and fulfilling the project's objectives.

The participatory journey commenced with a public presentation outlining the primary objectives of the project, along with the schedule for "Area exploration" workshops, meticulously organized by Urban Center Brescia. These workshops, comprising five open meetings for citizens, transpired between May and June 2022, strategically spread across various city zones. The core aim was to uncover disused, underutilized, or problematic public spaces ripe for transformation into active hubs, fostering both climate and social resilience. Participants were encouraged to envision these spaces as potential new squares for communal gatherings, small urban oases, play and relaxation zones, biodiversity gardens, rain-absorbing "sponge" areas, shaded and cool spaces, among other possibilities.

The workshops were structured around working tables equipped with city maps, facilitating a comprehensive understanding of the territory and idea exchange. Guided by the Urban Center Brescia team, participants engaged in discussions and dialogues, ultimately contributing to the completion of a proposal form for each nominated area. Proposers were prompted to provide a detailed description of the area, emphasizing physical and contextual characteristics, urban and environmental challenges, climatic vulnerabilities, and social factors. They were also encouraged to articulate potentialities and visions for the area, supported by initial ideas and accompanying visuals. In terms of social activation, proposers outlined potential subjects to be involved and identified beneficiaries of their ideas.

The culmination of each workshop featured proposers presenting their ideas, which were then placed on the city map displayed on the wall. Participants had the option to fill out the proposal form online through the municipality's website. For those engaging in workshops, geolocation was achieved by placing a sticker on a shared map. Online submissions required participants to enter the location on the interactive map following the digital completion of the form (Fig.3).


SOGGETTO PROPONENTE L'AREA

Specifica il nome della realtà del territorio (gruppo, associazione, consiglio di quartiere) a cui appartieni e in quale ruolo la rappresenti

LOCALIZZAZIONE

Specifica la zona e il nome del quartiere in cui insiste l'area

Specifica l'indirizzo dell'area (via e numero civico) oppure indica un luogo di rilievo nelle vicinanze

DESCRIZIONE DELL'AREA

Quali sono le caratteristiche fisiche e di contesto dell'area? (ad esempio: tipo di edifici e di servizi nell'intorno, passaggio dei mezzi pubblici, tipo di pavimentazione, presenza o meno di alberi, arredi urbani, ecc.)

Ritieni che quest'area presenti delle vulnerabilità dal punto di vista climatico? (ad esempio: zona soggetta ad allagamenti in caso di piogge intense, rischio di caduta alberi con venti forti, temperature particolarmente elevate in estate, mancanza di alberi e aree verdi, ecc.)

Ci sono dei fattori di criticità urbanistica e/o ambientale che vuoi evidenziare? (ad esempio: accessibilità difficile, eccessiva presenza di auto, alti livelli di rumore, scarsa qualità estetica, etc.)

Quali sono gli aspetti sociali che caratterizzano l'area? (ad esempio: tipi di persone che frequentano l'area, sicurezza percepita, ecc.)

POTENZIALITÀ E VISIONI

Come trasformeresti quest'area in uno SpazioAttivo? Esprimi qui la tua idea progettuale, tenendo conto degli obiettivi di aggregazione sociale, di riqualificazione urbana e di adattamento ai fenomeni del clima che cambia

SOGGETTI DA ATTIVARE

Quali quartieri e/o associazioni proponi di coinvolgere? Specifica chi sono e come li vuoi coinvolgere

BENEFICIARI DELLA TRASFORMAZIONE

Chi sono i beneficiari dell'area trasformata? Descrivi le tipologie di persone che frequenteranno lo SpazioAttivo

Fig.3 Form to be filled in for the proposal of areas

During the exploration phase, the completion of the form served as a crucial tool for gathering data on the proposed areas, documenting their location, and elucidating the specific characteristics justifying their nomination. The 56 reports received were geolocalized and made accessible on an interactive map, published on the open-source UMAP platform (Fig.4). This mapping initiative provided a visual representation of the proposed areas and their distribution across the city.

The exploratory workshops, integral to the participatory process, witnessed a total attendance of 135, involving 97 participants in total. This engagement underscored the active involvement and interest of the community in contributing to the regeneration and transformation of urban spaces through the "SpaziAttivi" project. The diverse perspectives and inputs collected during this phase laid a robust foundation for the subsequent stages of the project, ensuring a rich and comprehensive understanding of the nominated areas and their potential for positive impact.

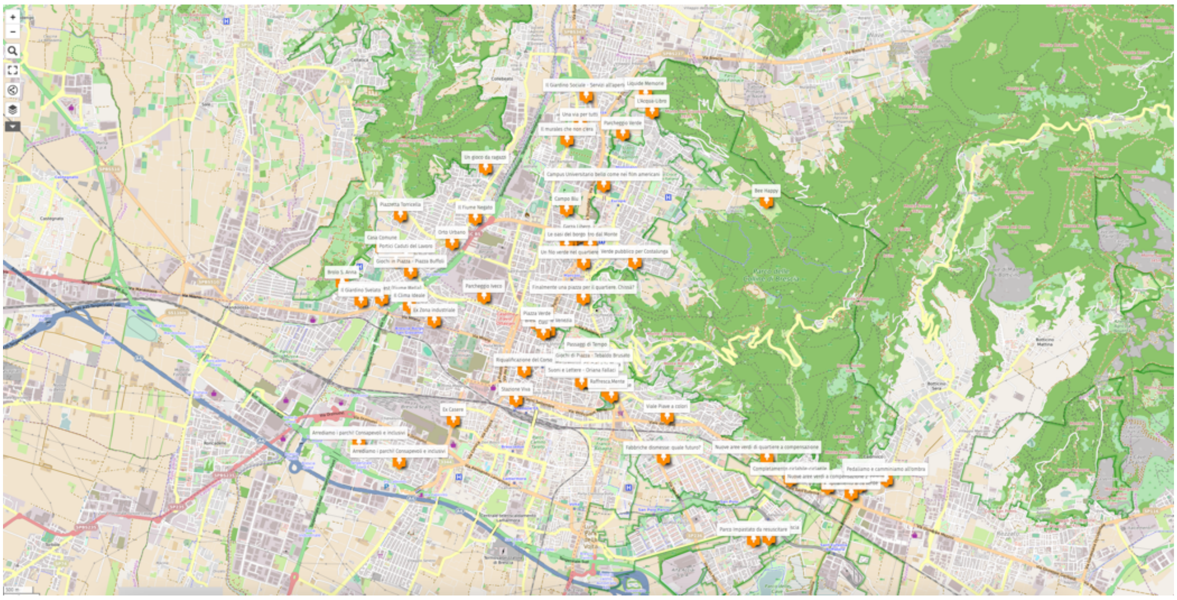

Fig.4 UMAP platform

Of the received proposals, a diverse range of urban areas were suggested for intervention:

- 23 proposals focused on green or natural areas, intending to enhance usability and functionality;
- 7 proposals targeted industrial or disused areas;
- 7 proposals centered around squares;
- 5 proposals were related to streets;
- 4 proposals focused on car parks;
- 4 proposals involved pedestrian paths;
- 2 proposals focused on neighborhood areas;
- 2 proposals targeted areas near watercourses;
- 2 proposals aimed at minor aesthetic improvements to buildings.

The assessment of ideas prioritized climatic and environmental factors, with 22 proposed areas incorporating sustainable mobility solutions. Additionally, 12 proposals included water management systems in public space design, while 11 emphasized biodiversity in space regeneration. Seven proposals suggested de-paving strategies.

The final workshop of the exploratory phase facilitated participants' viewing of the 56 proposals through an exhibition at the Urban Center. This setting provided opportunities for discussion, commentary on the work done, and the generation of new connections among participants.

The subsequent phase involved the analysis of proposed areas' typologies, verifying urban planning compatibility and technical feasibility. The working group conducted a quantitative analysis based on project objectives, evaluating factors such as climatic and environmental adaptation, experimentation and creativity, and community activation. These factors were assigned values reflecting their importance, leading to a ranking of proposed areas.

The ranking was later supplemented by a qualitative assessment, considering factors like the proposed area's position in the socio-urban context, potential socio-cultural impact, and the perception of social cohesion in community involvement.

The quantitative evaluation resulted in a ranking of the proposed areas based on the scores obtained from the assessment. These scores, representing the sum of the averages of the three factors (climatic and environmental factors, experimentation and creativity, community activation), were further supplemented with the evaluation of qualitative factors, leading to a new ranking.

In a subsequent typological assessment of compatibility with project objectives, 24 out of the 56 proposals were not considered for various reasons, such as scale, inconsistency with climate goals, overlap with other projects, or impracticality of intervention. Nineteen proposals were recommended to be sent to the Environment Sector for potential green projects, while 13 areas were deemed suitable to proceed, aligning with the objectives of the "SpaziAttivi" project and sector expectations.

Following this analysis, the working group, along with the Department of Urban Planning and Planning for Sustainable Development, selected areas to proceed with design activities. A final verification of stakeholder willingness was deemed necessary through interviews with the working group, focusing on the visions and objectives of various proposals and considering the relevance of factors assessed during the quantitative evaluation of the areas (climate/environmental factor, social factor, creativity factor). Proposers raised issues that the working group deemed necessary to report to relevant municipal councilors (Mobility Policies and Institutional Services, Public Education and the Environment, Green Areas and Parks, Housing Policies and Citizen Participation).

5. Results

Urban Center Brescia, in collaboration with the Department of Urban Planning and Planning for Sustainable Development and the Head of the Urban Planning and Mobility Area, has identified four areas for potential planning activities within the "SpaziAttivi" project. Following discussions with the proposers, the results were reported to relevant municipal councilors. Subsequently, two pilot areas were selected to proceed with the upcoming phases of the "SpaziAttivi" project in the year 2023-2024.

The two selected proposals are as follows:

- "Piazza Verde" (Fig.6): Located in the Carmine district, this area has been chosen as one of the pilot sites for the "SpaziAttivi" project;
- "Viale Piave a colori" (Fig.5): This area, characterized by colorful elements, has also been selected as a pilot site for the project's next phases.

Although the other two areas were not chosen for immediate planning activities, they are still deemed of interest to the administration and may be considered in future co-design and implementation processes within the "SpaziAttivi" project.

6. Discussion and conclusion

Tactical urbanism, a globally employed method of urban transformation, enables cities to swiftly alter the use of a space using temporary and cost-effective elements. This approach involves implementing reversible, accessible, and agile actions, such as colorful strips, street furniture, planters, or painted ground games. The effectiveness of these temporary interventions is analyzed, and the final design is adapted based on user reactions. Such quick and straightforward transformations serve to activate new dynamics and uses of space within local communities.

Fig.5 "Viale Piave a colori" (Piave Avenue in colour): paved area adjacent to the entrance of two schools, which was deemed feasible for the "SpaziAttivi" project

Fig.6 "Piazza Verde": a pedestrian area in the historic centre adjacent to the entrance of a primary school, considered feasible for the 'SpaziAttivi' project

Comparing the case study with cited examples reveals a distinct approach to area selection. While both projects emphasize the crucial role of community involvement, the identification of experimental areas in the case study is initiated through open meetings with the community, allowing them to propose intervention areas. Subsequently, the administration becomes involved for a detailed evaluation of the areas and the finalization of interventions.

The methodology employs qualitative and quantitative analyses with objective indicators, serving as the basis for the administration's decision on the choice of intervention areas. The two identified areas will undergo listening meetings with citizens to better understand the characteristics of the places and their potential for transformation. These working tables, facilitated by experts, involve citizens and stakeholders in the design of urban requalification from a tactical urban planning perspective.

While the proposed methodology efficiently identifies suitable areas for tactical urban planning experimentation, there is room for further refinement of indicators during the methodology phases. Continuous improvement in the assessment criteria could enhance the overall effectiveness of the approach.

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Fig.3: Comune di Brescia con il contributo di Fondazione Cariplo. (n.d.). *Strategia di Transizione Climatica - Un Filo Naturale - Una comunità che partecipa per trasformare la sfida del cambiamento climatico in opportunità*. Retrieved from: https://www.comune.brescia.it/sites/default/files/2023-10/231005_Presentazione%20progetto%20SpaziAttivi.pdf

Fig.4: Comune di Brescia con il contributo di Fondazione Cariplo. (n.d.). *Strategia di Transizione Climatica - Un Filo Naturale - Una comunità che partecipa per trasformare la sfida del cambiamento climatico in opportunità*. Retrieved from: http://umap.openstreetmap.fr/en/map/spaziattivi-urban-center-brescia_768501#15/45.5277/10.2879

Fig.5: Own production

Fig.6: Own production

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Urban forms interpretation for the car-era spaces reuse. A comparison of walking, automobile, and sustainable cities

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Abstract

The shape of the city is described in various ways, but it's not incorrect to view it as the result of intricate connections between tangible components and intangible influences, specifically the behaviors of its inhabitants. Over the last century, through the Modern Movement and the impulses of the CIAM, the studies of typological, technological, and stylistic innovation necessary to give the character of 'rationality' to the shape construction, summarized in the metaphor of 'machinist civilization', have produced infrastructures and urban spaces dedicated to the automobile efficiency. Today, the issue of sustainability is bursting into all sectors, shaping new urban and mobility models, mainly based on non-motorized travel. A situation not too different from that which has characterized cities in the past, in particular Italian realities.

Starting from these conditions and from the identification of a strong link between urban structure and mobility, the paper gives an interpretation of Italian cases able to connect the different components of the city, made up of spatial dimensions, represented by the urban structure, and temporal dimensions, identified in mobility patterns. Beginning with the walking city model, which is 30-minute walkable, the historic city, the rationalist one of the automobile city, and the polycentric structures are investigated to trace examples of design that can still be valid today and understand the possibilities to reuse the automobile-age spaces.

Keywords

Urban structure; Mobility patterns; Urban forms.

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1. Introduction

Sigfried Giedion, in 1954, in his well-known book *Space, Time and Architecture* says «A city is the expression of the diversity of social relationships which have become fused into a single organism» (Giedion, 1954, p.41). From this statement, we can conclude that the city can be interpreted as the product of complex processes of interaction that are established between material elements, such as streets, buildings, open spaces, and intangible components, represented by the uses and behaviors of citizens but especially by the flows of their movements, capable of profoundly shaping urban and territorial transformations. The form of a city, which by definition refers to the material and tangible part of physical space is, therefore, the result of the integration of social practices and activities, especially of interaction and movement, and mobility in this context is the element that innervates all aspects of urbanity (Urry, 2000).

Furthermore, new technologies have always found their primary application in transport systems, with deep implications for the city and its material and immaterial elements (Balletto, 2022), so much so that urban transformations have always been linked to the means of mobility, and the morphology of cities is the consequence of the technologies of the time in which they grew. In fact, many authors arranged the historic city for foot and horseback movements, the industrial city for rail transport, and the modern city for car use (Zanirato, 2020, p.89). For example, Newman and Kenworthy (1996) identify the mobility model of the *Walking city* in the historical city structure, while for cities built in the second half of the last century, they call about the *Automobile city* model.

In the past, urban planning and design have mainly focused on infrastructure spaces as physical elements, thinking of their functioning in terms of efficiency, technique, and speed. For several years now, however, these disciplines have been looking more and more at mobility as a possibility, as an aptitude, ability, and ease to move, to travel of individuals in the space of the city and the territory (Tira et al., 2021; Gargiulo et al., 2022). Also, numerous studies and investigations currently interpret the city as a composition of different units divided according to a metric determined by the temporal factor. After the Covid-19 pandemic, thanks to the recent Parisian experiment of the *Ville du quart d'heure*, interest in the 'chronourbanism' theorized by Carlos Moreno has increased (Moreno et al., 2021), but these ideas are based on numerous studies carried out in the past by the urban disciplines (Christaller, 1933; Jacobs, 1961; Gehl, 2009; Gehl, 2011; Hall, 2001; Perry, 1929). As highlighted by Moreno the concept of 'chronourbanism' and the choice of 15-minutes may seem arbitrary therefore he suggests adaptations based on the morphology and specific demands and characteristics of individual cities (Moreno et al., 2021). Indeed, many examples of studies suggest a wider range of metrics, such as the American examples of the 20-minute cities of Tempe in Arizona (Capasso et al., 2019), or Portland in Oregon (McNeil, 2011), but also the 30-minute cities (van Vuren, 2020). The common element of all these experiments lies in the approach, which is proximity-based urban planning, intercepted as the indispensable element to sustain the quality of life, provide for basic urban functions, and ensure sustainability and resilience in urban settlements. These examples, and many more, underscore the importance of the rhythms of city life in understanding urban dynamics and the central role played by travel and therefore mobility.

By considering mobility as a fundamental opportunity to rethink urban and territorial settlements and recognizing the strong relationship between urban structures and mobility, this study explores historical and current experiences related to how cities have responded and continue to respond to the social demands arising from the movement of goods and people.

2. Urban interpretation methods: urban structures and mobility patterns

As highlighted by the *III Habitat report*, the Italian territory presents a settlement structure composed of many urban centers (more than 20,000) mostly characterized by small size. Even today, about 42 percent of the Italian population resides in municipalities with fewer than 15 thousand inhabitants (Presidenza del Consiglio dei Ministri, 2016). Cities of the same size and characteristics were found by Newman and Kenworthy (1996) for the historical urban structure of the *Walking city*, a walking-based city whose destinations can be reached on foot in an average of half an hour.

At the same time, a project, whether it involves the territorial, urban, or architectural scale, can be considered as a work on potential space, only the use that the inhabitants apply within the built site can transform the potential into real space. The citizens are the effective producers of places, they adjust and modify the uses by attributing new meanings to the designed form (Mingardi, 2014, p.1280). Therefore, «to understand the city in its three-dimensional dynamism, to follow and modulate its process of self-generation, to connect and extend its tissue, a study of man is necessary to understand how human experience transforms the built form into an image» (Rykwert, 2003, p.307). Borrowing Rykwert's words, this study examines some urban structures by linking the different material components of the city and temporal issues, identified in the mobility patterns.

Historical and rationalist urban structures are the starting points of this interpretation; as mentioned above, Newman and Kenworthy associate these city typologies with the *Walking city* and the *Automobile city* mobility patterns. To best explain and clarify the elements and characters found in the literature, four Italian cases are used: the city of Venice and Urbino, and the district of San Siro and Pilastro. The research focuses on national case studies due to the already cited importance and peculiarities of the historic tissue in Italy, which, more than other contexts characterizes most of the cities and corresponds to the identified criteria.

Therefore, the cities of Venice and Urbino will be investigated, because in their historical layouts and at different scales, both manifest, in a clear and distinguishable form, the fundamentals and particularities of historical urban structures commonly found in many other national contexts. Also, the modernist experiments made in the San Siro (Milan) and Pilastro (Bologna) neighborhoods, with apparent different forms and structures, make it possible to clarify and delineate unequivocally the concepts and the characteristics of urban environments designed according to the theories of the Modern Movement. These case studies represent an emblematic sample for understanding the forms associated with the historical construction of the city and the later transformation phenomena that can be found in numerous other contexts.

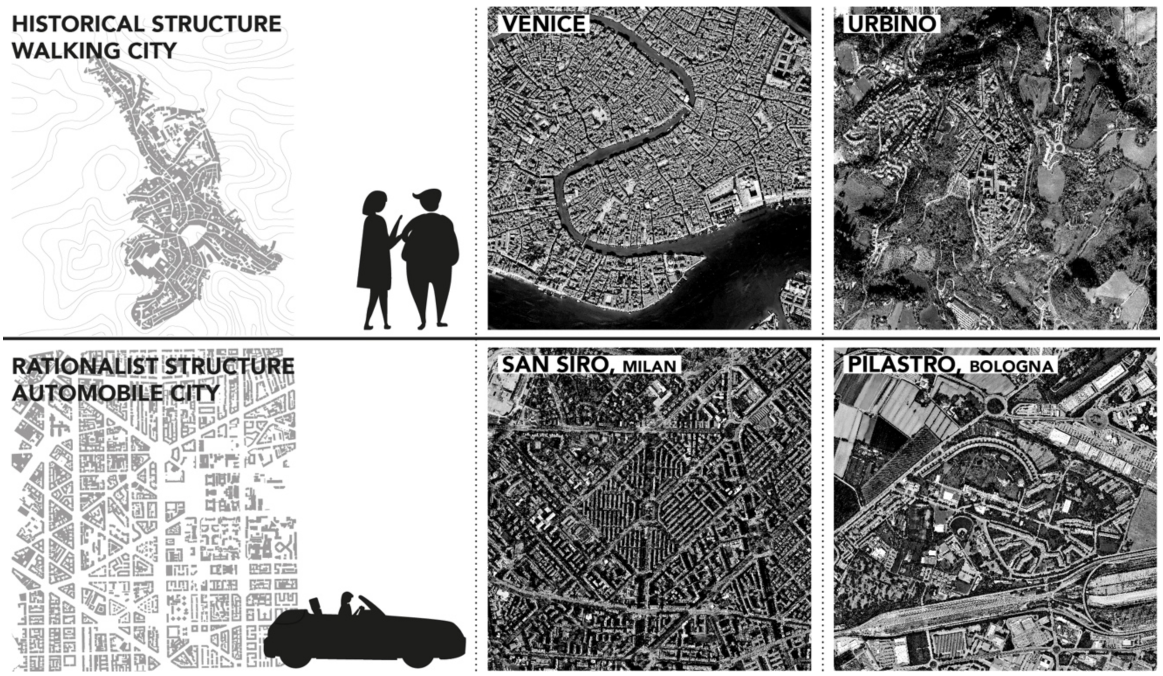

Fig.1 Aerial view of the four cases used for the urban forms interpretation

The framework used for the study focuses, on the one hand, on the material elements of dimension, density, land use, and geometry of the tissues; in parallel, some mobility patterns are intercepted, which are the ways and manners in which citizens transit within the city, analyzing the spontaneous use of urban spaces and the effects they have on the shape of the city and the mobility project. The interpretation grid is applied to the historical and rationalist urban structure and finally overlaps on the present polycentric structures.

Recognizing polycentric urban structures as extremely important for the project of sustainable mobility patterns, the reading tries to find points of contact between past experiences and current experiments to identify characteristics and requirements that contemporary mobility design is called to actualize. The framework and characteristics identified in past urban structures are finally found in current polycentric structures, investigating in parallel the results of design experiences that are now largely established and the trajectories of current policies and projects, the study aims to define the characteristics that mobility design must respect to ensure efficient, equitable and accessible urban systems.

This study aims to define new grids for understanding the urban phenomenon, but at the same time define characters and design criteria useful for drawing walkable 30-minute urban environments, like polycentric structures similar to the average cities that distinguish the Italian territory. It was decided to reflect on a temporal frame of 30 minutes as it was recognized as the most appropriate to represent the geography, the structure, and the conformation of the urban contexts most present and particularly characterizing the national territory. Therefore, focusing on 30 minutes seems to be an excellent opportunity for the replicability of the studies and for the possibility of suggesting different declinations of contemporary realities.

The survey, therefore, follows the historical evolution of the processes that have shaped urban structures and attempts to actualize principles and practices intercepted in examples from past eras that can still be valid today and, as Paolo Sica ably remarks for the methodology used by Le Corbusier in the development of *Toward a New Architecture*, also in this survey recourse to history is used to shed light on contemporary problems (Sica, 1991, p.136).

3. The historical structure of the Walking city

The first urban structure examined is the historical city, for which Paul Newman and Jeffrey Kenworthy intercept the mobility pattern of the *Walking city*. As Jan Gehl notes «In old cities almost all traffic was by foot. Walking was the way to get around, the way to experience society and people on a daily basis. City space was meeting place, market place and movement space between the various functions of the city. The common denominator was travel by foot» (Gehl, 2009, p.115) in the *Walking city* model, indeed, destinations can be reached on foot in an average of half an hour, which is why the city rarely stretches more than 5 km (Newman & Kenworthy, 1996, pp.27-28).

This structure is based on pedestrian mobility and its physical characteristics are represented by the already mentioned limited extension, due to the specific needs of the walking activities. Other properties are the high density and the mixed land use, always related to the conduct of the pedestrian behaviors, but also to the contained dimension of the urban settlements. Finally, the geometry of the tissues is ordered by the natural elements present on the different sites, topography and morphology are the forces that condition the urban project, therefore the streets present narrow and organic shapes (Fig.2).

Among the several historical cities, the famous American urban planner Lewis Mumford (1961) identifies in the medieval ones the most natural form of the city, which despite the sinuous layouts of streets and buildings (far from the strict geometry of the typical Roman land division) manages to appear equally orderly. In this type of city, the act of walking is the starting point for structuring, for creating urban form, because man «was created to walk, and all of life's events large and small develop when we walk among other people. Life in all its diversity unfolds before us when we are on foot» (Gehl, 2009, p. 19).

In medieval cities, the composition of the urban space is based on surprise, catching the whole scene with a single gaze is impossible so to properly understand the layout and arrangement of the elements, and to understand the functioning of the historic city, the third and fourth dimensions are indispensable; analyzing

the buildings, heights, and architectural details on the one hand, and the sequence of needs and temporal factors on the other are essential requirements for understanding this reality (Mumford, 1961).
Thinking about the apparent physical disorder of the old cities, we must realize that they have a complex social order guaranteed by the dense mix of different urban uses along the streets, an order that allows the operation of a wide variety of activities alongside one another (Jacobs, 1961). The lack of monotony and the succession of spontaneous and unplanned actions are what make moving through urban space a real experience and not just an action dictated by the need for movement.
Across history, urban areas have served as multifaceted gathering spots for urban inhabitants. Residents convened, shared information, negotiated agreements, and facilitated unions, while street performers provided amusement and merchandise was put up for purchase. Urbanites partook in both major and minor civic gatherings. Parades were organized, authority was showcased, and celebrations and penalties were executed openly (Gehl, 2009, p. 25). The entire city was a meeting place.
The open spaces are designed for the many practices that take place there from commerce to recreation or city assemblies, like the alleys and porticoes that are essential for protection from the weather and winds, follow more utilitarian than formal logic, that is also why they take on irregular shapes. However, the medieval city is not only a consequence of practical needs; it cannot be denied that there is in the construction of these structures an aesthetic awareness, an urbanism that reacted to the needs of life and accepted changes and innovations without allowing itself to be destroyed by them (Mumford, 1961).

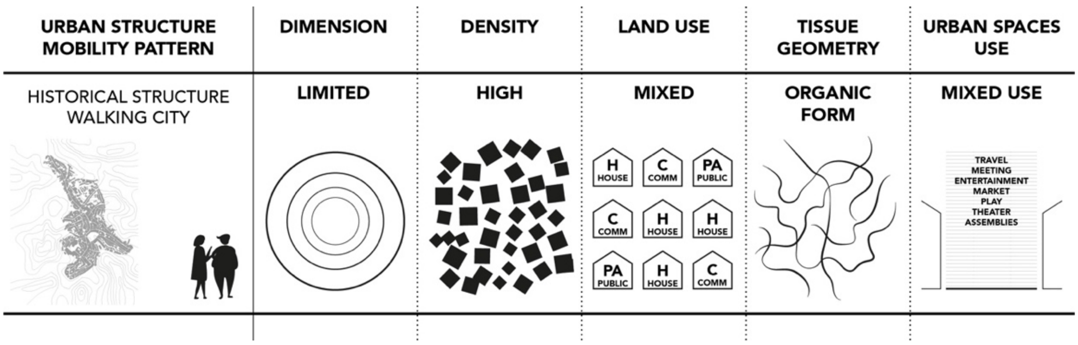

Fig.2 Interpretation grid of the historical cities

3.1 Italian cases of Venice and Urbino

The most iconic example of the medieval Italian city is Venice: no other city can show in a more schematic form the ideal components of the medieval urban structure. And none better prefigured, by its internal evolution, a new urban constellation that promised to overcome the ancient walled enclosure, such as had existed since the end of the Neolithic period (Mumford, 1961, p.321).
Despite its richness of streets, alleys, and squares in varying sizes, the fundamental structure of Venice is uncomplicated and simple, focused on a few central streets that link main locations and a clear distinction between major and minor squares. The city's entire design revolves around a framework that facilitates direct pathways and a handful of significant but essential areas (Gehl, 2009). An arrangement that logically adheres to the most convenient walking paths and permits more attention to enhancing the quality of each space and the whole itinerary. In Venice, it's still common to take 10,000, 15,000, or even 20,000 steps in a typical day, these distances don't feel significant due to the multitude of experiences along the way and the sheer beauty of the cityscape (Gehl, 2009). The canals are additional pathways and boundaries between the different parts of the city, water strips that also serve as roads, like the green belts and highways of a well-designed modern city, the lagoons serve as inviting water promenade and park in one, where the water replace the agricultural landscape of the mainland (Mumford, 1961, p. 323).

Looking at the evolution of San Marco Square, its form and content can be defined as the product of an accumulation of urban purposes and uses, modified by the stratification and succession of different instances, functions, and times imposed by the spontaneous use of the community. An «organic products that no single human genius could produce in a few months over a drafting board» (Mumford, 1961, p. 322).

Therefore, the medieval city plan is not conceived as a static design that responds to the necessities of a specific generation by rejecting any possibility of transformation, rather it tangibly expresses these mutations by creating a unity that emerged from a complex order (Mumford, 1961, p. 322). Equally and quite naturally, in the space of San Marco Square, gradually political and especially social functions substitute the original purposes of the place related to commerce and agriculture, which find locations in other areas of the city. The San Marco pattern is also replicated on a smaller scale in every city parish, «each has its campo or square, often of an odd trapezoidal shape, with its fountain, its church, its school, often its own guildhall» (Mumford, 1961, p.323). This settlement typology depicts an urban structure that can easily be attributed to polycentrism.

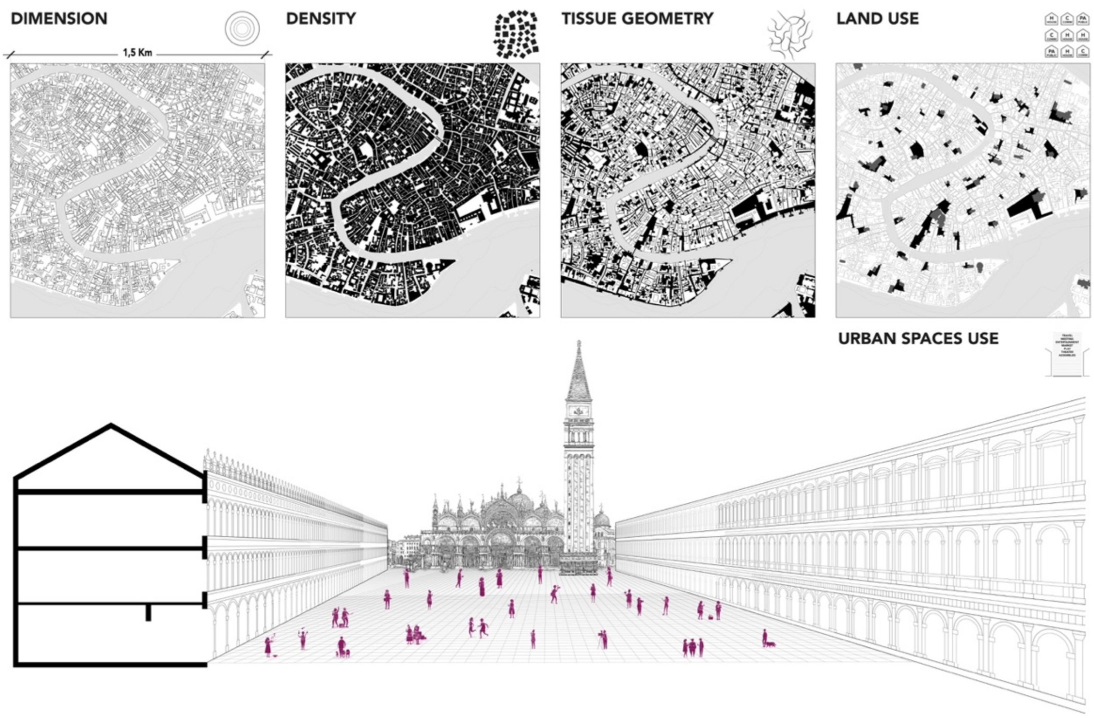

Fig.3 Decomposition of the Venice Case

Surrounded by the mid-Adriatic hills, between the Foglia and Metauro Valleys, settle on two hills is situated the small Urbino. A town with a similar urban structure to Venice but located in a different geographical context and on a smaller scale. His history and particular aesthetic qualities are closely linked to the *Palazzo Ducale* and the historical figures of Francesco Di Giorgio Martini, and in modern times, to the architect Giancarlo De Carlo. About this town, De Carlo says «Few historic cities have, as Urbino, such a measured and fine mixture of the grand and the popular, the emblematic and the direct, the exciting and the heartbreaking: such a complex and textured urban continuity. Which is found especially in the oldest areas of development» (De Carlo, 1966, p.79). He remarks, that although the most relevant urban interventions are later than the years of the Middle Ages, no intervention of the Italian Renaissance completed with greater coherence the program of building a continuous and unified urban space, starting just from the urban texture of the medieval period, from the same characteristics, intercepted also in Venice.

The composition of the urban landscape of Urbino is closely linked to human motion; the volumes of the *Palazzo Ducale* rotate from the square to the apartments section, and in the rotation, the architectural language also changes, this approach is reflected and amplified in the surrounding buildings, creating an articulated sequence of urban spaces (De Carlo, 1966). To emphasize the relationship between the geometry of the tissues and the harmony to the context, De Carlo points out that «the architects of Urbino had a global conception of the relationship between context and form» (De Carlo, 1966, p.77).

In Urbino, the *Mercatale*, in particular, is the entrance area to the city for those coming from Rome, the magical place of conjunction and separation (De Carlo, 1966, p.79). It is a large artificial surface designed by Francesco di Giorgio Martini, obtained by covering a valley, and was, from the 15th century forward, a meeting place but also a site of interchange, commerce and play; it hosted markets, but also circuses, fairgrounds, and events of the most diverse kinds, as in the case of San Marco's Square in Venice, highlights the flexibility of use characteristic of medieval urban spaces. In 1974, when the new Plan for the city was being prepared, it was again Giancarlo De Carlo who intercepted this as an extremely strategic area for mobility.

In fact, *Operazione Mercatale* envisioned several actions that, in their synergy, rethink the qualities of the ancient public space to adapt them to new and changed needs. Below the large horizontal plan was planned to be a garage to preserve the historic city from cars, while a bus station was to be located above. A network of pedestrian paths to the Fort Albornoz and interventions to restore various artifacts such as the reopening of the *Rampa di Francesco di Giorgio* and the restoration of the Theater were also planned. Of all the interventions De Carlo managed to realize only the last two and the garage.

In *Operazione Mercatale* he builds a spatial sequence between new and pre-existing areas, a dynamic exploration of architectural and urban space. To maintain it as a common space for people to gather, socialize, and engage in recreational activities, it was envisioned that the structure of the underground garage would be hidden beneath a layer of earth. The project provided for the paving a material resembling the color of Urbino clay, known for its pedestrian traffic durability. It needed to be strong and lightweight, as motorized vehicle access would be restricted to exceptional situations.

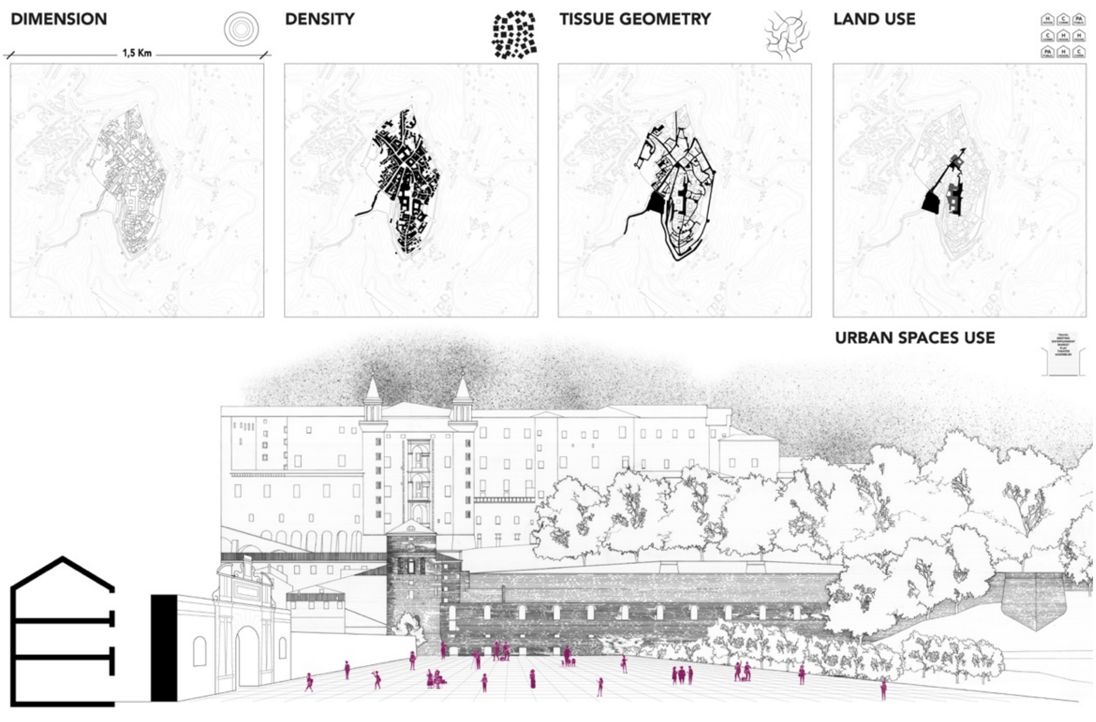

Fig.4 Decomposition of the Urbino Case

4. Modernist cities and the mobility pattern of the automobile

The most immediate and concrete example of the difference between pre-modern and modern times lies just in the street layouts that from the eighteenth century acquired autonomy from the context and sinuous lines of river systems and hill and mountain slopes (Farinelli, 2003, p.15). The Industrial Revolution era marks, in these aspects, a critical point in the history of city development, urban rail networks becoming the new backbone of the geographical organization of settlements in the territory. The new supply of rail mobility is decisive for territories and cities that shape up by following instances dictated also by new housing patterns related to the spread of industries.

However, it is since the post-World War II period that the structures of large cities have changed significantly. Population growth, the rise in demand for travel, new cultural and economic patterns such as new spatial relationships between home and work, and the widespread use of private cars, led to the emergence of the *Automobile city* (Newman & Kenworthy, 1996, pp.31-33). The mass use of cars is the foundation of modern urban structures whose physical properties are unlimited sprawl, low density, specialized land use, and wide linear roads designed exclusively for the efficiency and speed of cars (Fig.5). Proximity is no longer a fundamental need since the automobile opens up the possibility of reaching more faraway destinations, so the city grows horizontally occupying more and more available spaces.

In Europe, the destruction due to war also leaves large voids within consolidated cities, often in highly strategic areas such as infrastructure and mobility networks. In Italy, in particular, the most important growth happens in these years coinciding with the advent of the mass automobile distribution giving rise to what Campos Venturi calls the *'genetic anomaly of Italian cities'*, (anomalia genetica delle città italiane) that is, the characteristic that heavily links, more than in other European contexts, the growth of the city to the automobile model (Campos Venuti, 2001).

In opposition to the historical city, modern urbanism, which spread in Italy with the plans after World War II, following the theories of the Modern Movement, is based on a principle of order founded on desegregation, and the specialization and separation of elementary land uses, which are assigned an autonomous and isolated location. This happens because the structuring unit of the city is no longer the street but the block (Farinelli, 2003, p.125). In examining the newly formed neighborhoods, a new perspective on the city's physical growth emerges that focuses on the dense presence of *functional values*. This concept envisions the city as a collection of distinct *neighborhood units,* each individually defined and unitarily solved (Scaglia, 2014, p.87). Each building of the units is integrated into an organic urban layout within the neighborhood boundary, representing a stark departure from the morphology of the pre-existing city.

The articulation of space and the interrelationships between individual buildings are now prioritized differently from the traditional emphasis on materials that shape and define the urban environment, like public spaces and street layouts. The structuring is assigned to simple positional associations between architectural objects, the main rules look at the integration and juxtaposition only of simple different building typologies (Scaglia, 2014, p.90). To create an ideal and homogeneous urban structure the formal composition takes the meaning role and the architecture has a well-defined representational goal.

It is at this time, moreover, that the process of oversimplification that had already begun in the Baroque era reaches its peak: as Mumford reminds us some of the best and worst examples of Baroque town planning are from a time when they had ceased to be symbolically or practically appropriate to the historical period that expressed them (Mumford, 1961, p.401). In the *Automobile city*, space and landscape are shaped by the necessity of the motorist who, traveling at higher speeds than the average 5 kilometers per hour of the pedestrian, needs simplicity to enjoy the context and not be overcome by it. As a result, large symmetrical streets are established, enclosed views are removed, and straight lines and uniform building arrangements take precedence. The gradual dissolution of built space and the consequent expansion of empty areas gives rise to new dimensions, rhythms, and measures of open spaces (Scaglia, 2014, p.90). In this spirit, boundaries do not exist and disappear. Distances and travel patterns dilate, pressing the model of the automobile as a symbol of modernity, speed, and efficiency of city living. Urban space is organized by making it continuous, reducing it to order and measure associated with the space-time paradigm less time and more movement. Urban boulevards become more straight to quickly connect distant places, wider and wider to accommodate as much traffic as possible, and become obstacles to crosswalks and pedestrian connections between spaces that are instead very close; in the rationalist city, it becomes easier to move to distant directions than to proximity areas.

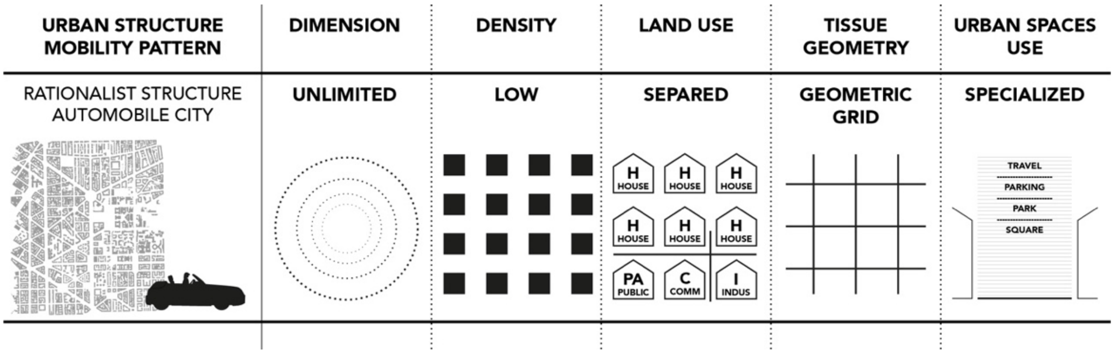

Fig.5 Interpretation grid of the rationalist cities

4.1 Italian districts of San Siro in Milan and Pilastro in Bologna

In Italy, a significant transformation began in the 1930s with the development of three neighborhoods in the city of Milan, characterized by a strong sense of unity. These neighborhoods were created by architects Franco Albini, Renato Camus, and Giancarlo Palanti, who employed the principles of maximum unification, juxtaposing similar typological elements (Galliani & Spinelli, 2014). The *San Siro District*, in particular, looks like one of the most explicitly rationalist Italian examples. Is a quadrilateral built on two wide triangular areas organized on the main streets of *Mar Jonio Buolevards* and *Aretusa Street* in the north of the city, built between 1935 and 1947. The project for the western part, known as *Milite Ignoto*, was designed by Albini, Camus, and Palanti. In this area, there are 2.925 residential units, and when combined with the 3.208 of the eastern part, the entire San Siro district comprises 6.133 apartments.

The morphological and typological principles brought forth by the Rationalist Movement, especially through the work of these three architects, turned this new neighborhood into a landmark and a pioneering element within the urban landscape. They introduced the concept of the *open urban scene* by refining the elements of urban imagery at the block level, shaped by the interplay between parallel buildings and open spaces (Galliani & Spinelli, 2014). The guidelines used in the project were economy, optimization, and standardization of aggregative principles. It is a neighborhood consisting mainly of residential buildings, with no particular functional heterogeneity or a uniform grounds plan (Cognetti, 2014, p.112). The rigidity of the street grid that structures the new neighborhood has produced an *inner suburb* today, very different from the urban context that has developed around it, as the expansion of the city of Milan has spread the boundaries of San Siro have become even more evident designing a geography of separation that touches high levels (Cognetti, 2014, p.114). The seriality and monotony of the buildings make the design of the neighborhood rigid in space and static in time, a uniform block, fixed and frozen for eternity, using an abstract form that bounds the social contents rather than arising from it (Mumford, 1961).

Through the separation of the built-up area from the street layout, the principle of parallel buildings introduces new connections between city blocks and public urban spaces. The construction of these blocks is redefined, shifting the focus away from aesthetic considerations of facade decoration along public streets. Instead, the main issue becomes the quantity and typologies of the habitable space within the buildings (Scaglia, 2014, p.90). The attention of the architecture is directed inward, to the optimization of the living spaces, rather than toward the external common areas. However, the specific and innovative aspects of this urban initiative, such as the uniformity and the lack of contextual adaptation, which refers to the indiscriminate application of the project in any urban setting, have now become the main challenges that undermine both the significance and the long-term utility of these residential areas, making them susceptible to instability. The lack of support services for the resident community and the substandard quality of open spaces are critical issues today, but they also offer tangible opportunities for comprehensive improvement through internal building adjustments and the redesign of open spaces (Galliani & Spinelli, 2014).

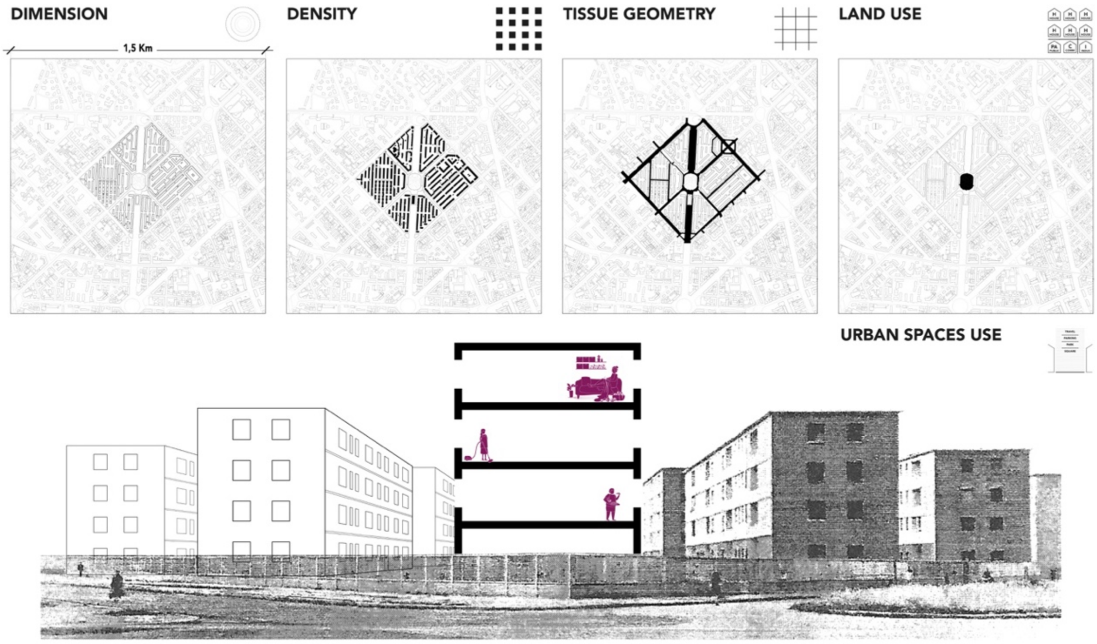

Fig.6 Decomposition of the San Siro Case

Another example, different from the formal approach of Albini, Camus, and Palanti but similar in results, is the *Villaggio Pilastro* in Bologna, a project by architects Francesco Santini, Giorgio Trebbi, Glauco Gresleri, and the engineer Giorgio Brighetti. The initial purpose was the implementation of a wide-scale urban plan to settle about ten thousand inhabitants by creating a self-sustaining core. Located between two high-voltage power lines, the settlement is structured as a linear park. Residences are arranged around this large open space, along irregularly shaped streets that recall the sinuous lines of medieval cities (Mingardi, 2014, p.1277).

Compared to the case of San Siro in Milan, the typological experimentation in Pilastro focuses on different building typologies, combining towers, in-line blocks, and townhouses. The central park serves as a link to the main access road and is a focal point where important public and common services are concentrated. From the center of this kind of square, the dense residential structure, composed of buildings in a serpentine line, branches out. The shape of the buildings is designed to create changeable spaces between them that serve as catalysts for social life. Rather than focusing on a single element, the architects' attention is directed to the overall composition to create urban scenes in a place where they are naturally absent, using a design rich in complexity that attempts to reconstruct typical urban dynamics that are not easily found in such an isolated area (Mingardi, 2014, pp.1277-1278).

Despite careful planning, the neighborhood cannot reproduce the needs of communities typical of the historic city where social arrangements are the result of the stratification of many generations and in which continuous unplanned contamination takes place (Mingardi, 2014, pp.1283). Although the district is the result of layered interventions, it is not possible, in the case of the *Pilastro*, to talk about stratification. Like San Siro, the neighborhood today is configured as a place enclosed within its margins, unable to accept disturbances from the surrounding city despite its large open spaces; the lack of boundaries is equally capable of generating an alienating public environment (Sendra & Sennet, 2020). In its streets and parks, the intense flow of daily life does not happen, public dimension is absent, and the lack of attractions and spaces adequately designed to human needs means that «the concrete statues shaped by the sculptor Nicola Zamboni seem to be the only users of the space» (Mingardi, 2014, p.1284). In the end, the planners' persistent efforts to create spaces that encourage socialization have proved unsuccessful; the scarcity of human presence is a defining feature of *Pilastro*, an absence that becomes all the more significant when one considers how meticulously the place has been designed and organized specifically for social interaction.

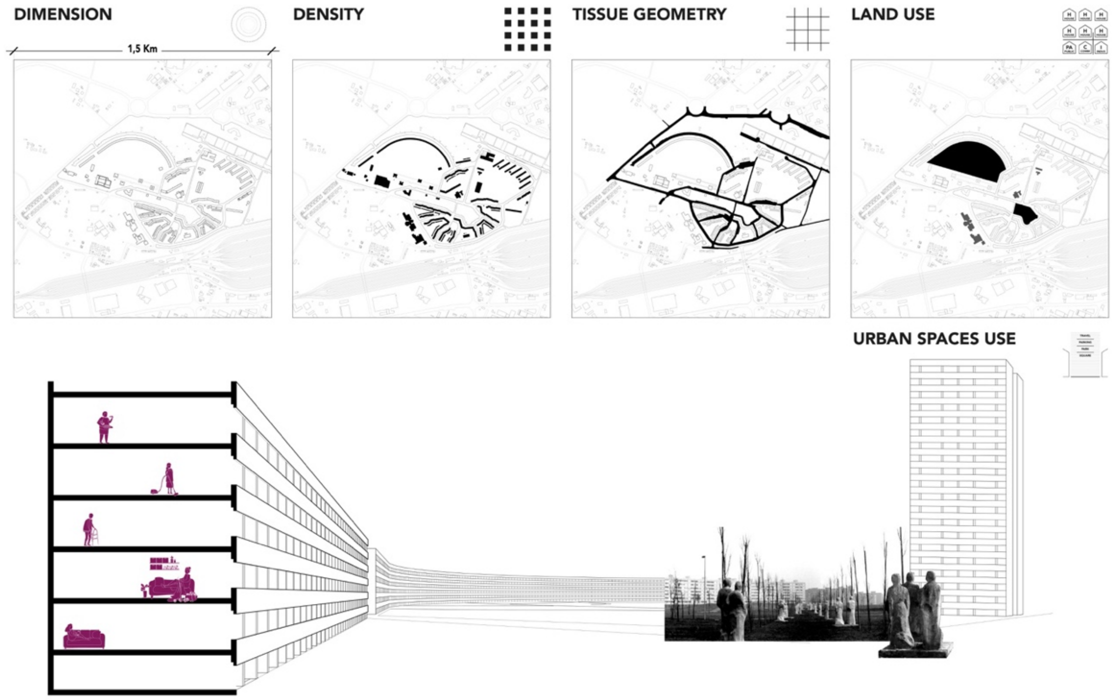

Fig.7 Decomposition of the Pilastro Case

5. Conclusions: sustainable city, the polycentric way

It has now been largely demonstrated that the history and development of urban settlements have always been conditioned by mobility; particularly, the rise and diversification of routes for moving people and materials has significantly influenced urban and territorial planning (Cutini, 2003). The approach to the city as a rationalist expression of a well-defined function is in crisis today; instead, there seems to be a growing need to interpret it as a system of several fragmented and self-sufficient components. New urban models and approaches adopted, pursue the idea of a multipolar system measured by time-of-use metrics (Bocca, 2021). Looking at the debate regarding the polycentric urban model, the focus is mainly on the variety and diversity of functions, their distribution, and the consequent relationships of integration and interdependence among different cores, highlighting the major role played by mobility.

A polycentric city therefore is a spatial structure made up of distinct centers linked to each other by a series of complex networked relationships, the city of Venice, quite spontaneously and in very distant times, consists of an example of a polycentric city. The structure of St. Mark's Square and parish-satellites generates an open nuclear form with the same characteristics searched for today for the *X-minute cities* or the *complete neighborhoods*, which are based on the principle of proximity and for which high density and mixed land use are an indispensable prerogative.

As Gehl (2009, pp.12-13) remarks «Venice has everything: dense city structure, short walking distances, beautiful courses of space, high degree of mixed-use, active ground floors, distinguished architecture and carefully designed details — and all on a human scale. For centuries Venice has offered a sophisticated framework for city life and continues to do so, issuing a whole-hearted invitation to walk». Many ancient cities were originally designed as pedestrian-oriented urban centers, and in some cases this role persists. For example, in Urbino, thanks to the careful vision of Giancarlo De Carlo, in the 1960s coinciding with the explosion of the mass use of the automobile, it was decided to leave all automobile traffic-related facilities

outside of the historical parts of the city. He considered the motor car a completely extraneous element for these urban tissues that are closely designed in relation to human movement. The arrangement of the city's architectural elements in Urbino, more than in other places, relies on visual connections that would be incompatible with the perspective of a motorist. Indeed, De Carlo writes «No attempt at rationalization would overcome the intolerance of the city's form to a mode of circulation extraneous to it because the correlations that exist between built surfaces and volumes are directly related to human movement, and only in the constant explanation of this relationship the basis of an absolute spatial continuity can be recovered» (De Carlo, 1966, p. 77). Just as Giancarlo De Carlo did in Urbino, a similar transition from fast to slow traffic in Venice takes place at the city limits rather than at the front door. This approach is thought-provoking and offers inspiration for the modern concept of creating sustainable and healthy cities (Gehl, 2009, p.95).
The theme of density, emerging from the historic city, continues today to represent an indispensable paradigm for polycentric structures, particularly for the dense system of medium-sized cities that scatter the Italian territory. The territorialization of services implemented in Barcelona with the *Suprilles Plan* since 2014, for example, has been successful because it has enhanced and powered the existing urban density (Manzini, 2021, p.103). Equally, Moreno's theory but also Italian experiments, for example, in Milan through the *Piano dei Quartieri* or in Turin thanks to the *Integrated Urban Plan*, are based on the proximity between origins and destinations, but especially in the concentration and centrality of activities (Rossetti & Zazzi, 2019) for which density is a vital precondition. However, as Gehl remarks «we often see that poorly planned high density actually obstructs the establishment of good city space, thus quenching life in the city» (Gehl,2009, p.68) and this is evident if one thinks about the case of the *Pilastro* neighborhood whose over-extension of open spaces causes the citizens' disuse. Therefore, the issue of proximity and consequently density also turns out to be closely linked to the real capacity of infrastructure to host functions and users, and thus the quality of places is essential to ensure the use or reuse of these spaces.
Regarding tissue geometry, while it is true that narrow Parisian streets permitted the French Revolution so much that Mumford calls them the last refuges of urban freedoms (Mumford, 1961), contemporary experiences show the great potential of wide boulevards and street space provided by the rationalist city. Always consider the *Superilles* case, the reticular grid designed by Ildefonso Cerdá in the mid-19th century is reused with a total rethinking of mobility, excluding car traffic from some streets without completely eliminating it; the roads inside the Superblocks are therefore transformed into spaces more accessible to the pedestrian, as well as less noisy, greener, and more pleasant, and this is mainly due to the large size of the street space. A similar strategy makes in Italy is represented by the *Piazze Aperte program* of the Milan city (Comune di Milano, 2022), one of the most successful national examples of tactical urbanism, again the space of cars, either for movement or parking, is reappropriated for pedestrian circulation and to create wide public spaces. The case of the *Superilles* also shows that the rigid geometry of the street layout of the automobile city is not necessarily a problem for the reuse of this infrastructure, geometry can still have a positive function in the design of the city. The use of geometry in urban planning can be used to guide and enlighten pathways but, like all processes of abstraction, it must always be linked to the concrete situation and variety, offering solutions that give way to the specific expression and aspects of city life overlooked by the pure application of the rule (Mumford, 1961, p.393).
Finally, regarding the use of space and thus the immaterial component of the city, it seems clear that «The new mobilities paradigm suggests a set of questions, theories, and methodologies rather than a totalising or reductive description of the contemporary world» (Sheller & Urry, 2006, p.210). As shown by the social and community failure of San Siro and Pilastro, but not only in these cases, it is necessary for planners and architects today to think of cities as «a multi-purpose, shifting organization, a tent for many functions, raised by many hands and with relative speed. Complete specialization, final meshing, is improbable and undesirable. The form must be somewhat noncommittal, plastic to the purposes and perceptions of its citizens» (Lynch,

1960, p.91). Pablo Sendra proposes infrastructure as the starting point for a continuous and open process, the primary space for creating conditions and procuring possibilities for change without imposition, through a design of public places as the result of community-led actions and negotiations (Sendra & Sennet, 2020, p.73). The multifunctionality and hybridization characteristic of places such as the *Mercatale* in Urbino now appears as an indispensable prerogative for the reuse of infrastructure spaces. The great vision, later betrayed in the work execution, of Giancarlo De Carlo in the *Operazione Mercatale*, lies not only in the perfect construction of a dynamic exploration of architectural and urban space but in the choice to preserve the public, social, and mutable characteristics of the place. De Carlo's approach outlines a method of action that is markedly linked to an interpretation of the city and the experiences and practices that turn into it. He believes that the essence of space is shaped by the life it accommodates, and it is this life that defines its various interpretations. Consequently, in his efforts to return architecture to the public without compromising its fundamental role in societal change, he crafts solutions that are rooted in the lived experience of space. He arranges volumes from the inside of the structure and seamlessly integrates them into the urban environment, embracing a fluid and organic design approach (Romani, 2001). A recent example, very similar to De Carlo's intentions for the *Mercatale* parking, is the *Park'n'Play*: an architectural experiment made by the Danish study *JaJa Architects*, as part of the extensive program of actions for the regeneration of the Copenhagen Port. In this case, the intervention at the scale of the building becomes an important urban opera; the large infrastructure of multi-level parking, usually dedicated to the car, hosts within it a large playground and green spaces, giving a real example of hybridization, multifunctionality and actualization of the new forms of automotive infrastructure spaces.

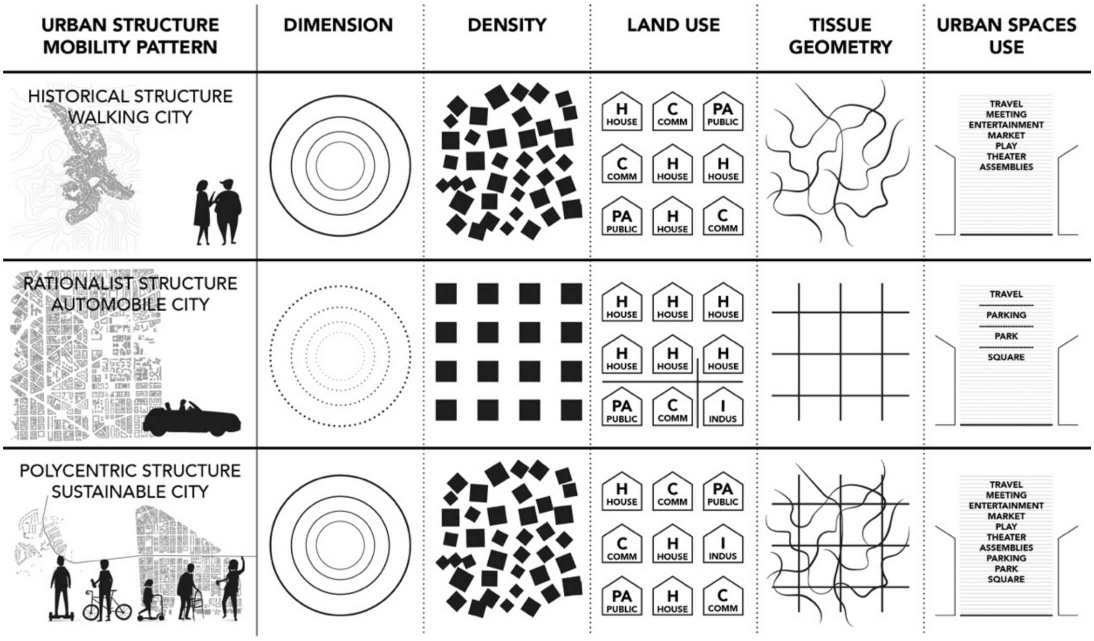

Fig.8 Comparison grid of the historical, rationalist, and polycentric cities

In conclusion, paraphrasing Mumford's statements, it is not seriously thought that we can solve urban mobility problems by restoring a more primitive technological or social base (Mumford, 1961), rather it is necessary to understand how we can make the best of the past experiences and how these can be actualized in the present and future; because just as the automobile shaped the 20th-century city with all its deformities, the new mobility systems of the third millennium, could redefine the use of urban space with a new, more balanced layout (Zanirato, 2020, pp.89-90). Therefore, it is important to identify the many urban situations, not only for their problems but also for their real different needs and possibilities. The city is not a white page (Bellmunt, 2021), and we need to interpret urban space for the juxtapositions and relationships that bind different layers, from historical qualities and facts to spontaneous and unplanned uses.

In addition, the proposed methodology, by interpreting urban transformations through mobility and observing the ongoing phenomena at different scales, made it possible to bring together the spatial and temporal dimensions of urban dynamics (Pucci, 2015, p.41). The use of the specific lens of mobility also allowed for a study of the city, its forms, functioning, and spaces, from the practices that take place in it. The comparison with the rhythms with which people inhabit and use the city for the mobility project seems indispensable because, within urban areas, mobility is «part of the social production process of time and space» (Cresswell, 2006, p.5) and is therefore capable of describing the space-time variability of urban practices and with it the transformations of the contemporary city (Pucci, 2015, p.40).

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Capturing city-transport interactions. An analysis on the urban rail network of Palermo (Italy)

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Abstract

Transit Oriented Development (TOD) and 15-minute City (15mC) are two planning concepts that, in different ways, have attempted to provide alternative solutions to the car-centered development model characterizing modern cities. The paper presents a methodology that seeks to integrate the TOD and 15mC principles in an analytical perspective, with an application in a rail station area of Palermo, a Southern European city plagued by inefficient public transport and traffic congestion. The study aims to define and compare two different station areas based on their socio economic, functional and environmental dimensions including accessibility and built environment.

The paper is divided into six sections, including the work's theoretical framework, the description of the railway system, the methodology that explains indicators used for the analysis and discussion about the comparison of two case studies. In the final part of the paper we critically outline the potential of this approach for future investigations and explain the novelty of the research with integrated analysis of the city-transport interaction around two different node.

Keywords

15-minute city; Transit oriented development; City-transport; Railway network; Palermo.

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1. Introduction

As cities continue to gradually attract people and economic activities, the issues regarding traffic, mobility, and accessibility to essential amenities are also getting more complicated. Today, most cities are trying to find solutions to traffic congestion, pollution and other related problems while increasing the accessibility of people to functions which eventually leads to an environment for latest urban development strategies and paradigms. A prevailing convergence among numerous novel concepts and strategies is the proposition that urban centers ought to curtail vehicular utilization while endorsing and facilitating active mobility modalities.

Today, the continuing decentralization of cities is a widely documented phenomenon (Bertolini, 1999). The dynamics of urban planning have been changed by the car-centered conception and it paved the way for urban sprawl and its destructive results (Brown et al., 2009). At the core of this research paper, both Transit-Oriented Development (TOD) and the 15-Minute City (15mC) stand as urban development concepts born out of the response to the challenges posed by car dependency.

TOD is an approach that seeks to integrate transport and land-use planning to achieve greater accessibility to relevant urban functions while increasing the efficiency of public transportation by densifying population and activities around the transit nodes (Cervero, 2004; Suzuki et al., 2013). Following pioneering experiments in the USA, which initially concentrated on central station areas of metropolitan regions (Cervero, 1998), the TOD concept has evolved to encompass a diverse range of projects with varying objectives and geographical settings. This expansion now includes suburban and lower-density urban settlements (Thomas & Bertolini, 2020) but also the regeneration of existing (sometimes deprived) neighborhoods.

The successful implementation of the TOD model depends on the five Ds: density, diversity, design, distance to transit, and destination accessibility (Ewing & Cervero, 2010). These principles exhibit similarities with the dimensions of the 15mC concept, making TOD a compatible model where high-quality walking and cycling networks can be combined with an efficient public transport system to increase proximity.

15mC concept rides on the idea of chrono-urbanism which suggests that the quality of urban life is inversely proportional to the amount of time invested in transportation, especially using cars (Moreno et al., 2021). Revived as an urban recovery strategy during the Covid-19 pandemic (Moreno et al., 2021), the 15mC concept places a stronger emphasis on ensuring citizens' access to essential services rather than the extensive connectivity and daily commuting typical of traditional TOD approaches. Key tenets of the 15mC's approach to revitalizing neighborhoods encompass the principles of proximity, diversity, both in social and functional terms, and above all, walkability. This concept underscores a deep-rooted sense of place and community, drawing parallels with neighborhood planning paradigms of the past, such as Perry's "neighborhood unit" (Jacobson and Forsyth, 2008), while also highlighting its pursuit of adaptability and temporal flexibility in reshaping urban spaces (Pozoukidou & Chatziyiannaki, 2021). As mentioned by Abdelfattah et al. (2022b), the emergence of the 15-minute city model reconfigures the density of built structures inherent in the well-established TOD paradigm, offering an inventive and more intricate iteration.

Both the TOD and 15mC concepts share a substantial foundation of common guiding principles (Büttner et al., 2022; Jacobson & Forsyth, 2008; Khavarian-Garmsir et al., 2023; Thomas et al., 2018). This becomes particularly relevant when it comes to strategic design, urban policy and spatial planning which can benefit from a holistic approach that is able to account for a broad array of aspects. This becomes particularly relevant when it comes to strategic design, urban policy and spatial planning which can benefit from a holistic approach that is able to account for a broad array of aspects.

First and foremost, the success of these approaches’ hinges on the presence of a built environment rich in diverse functions and amenities, as these are what make neighborhoods appealing to both residents and city users relying on public transport. Additionally, accessibility to these functions is of paramount importance to both paradigms. This accessibility is ensured by their proximity to residents' homes, the provision of high-quality public spaces and pedestrian-friendly streets, as well as efficient connections to secondary mobility

networks (e.g., shared mobility). These measures aim to reduce car dependency and secure seamless first/last-mile connections to the transportation network if needed.
There are also slight differences in the way the two paradigms relate to space and, consequently, to the planning instruments that address urban change. As the effectiveness of the TOD concept is often depended on the efficiency of a wide, long-range, transport network, its principles should be embedded into a metropolitan or even regional development strategy. This makes the success of TOD experiments linked to the coordination of a broader range of policy sectors and stakeholders, first of all those responsible for transit. In contrast, despite its attention to long-range connectivity remains high, a number of 15mC experiments looks at the scale of the district/neighborhoods as its preferential spatial target. This makes urban design – and even community-led co-design processes – the planning approaches that give the 15mC concepts more chance to be implemented. Tab.1 presents analogies and differences in the main principles behind the two above mentioned concepts.

Transport Oriented Development	**15-Minute City**
Scale and density	Proximity Density
Variety and complexity Car movement and parking	Mixed-use Diversity Flexibility
Connections Transit in the urban pattern	Connectivity Accessibility Modularity
Public spaces for human use Safety Pedestrian/cyclist orientation	Human-scale design Livable public spaces
Diversity	Diversity
Smart mobility	Digitalization
Timeframe Programming	Adaptability

Tab.1 Overlapping principles behind the TOD and 15-Minute City concepts

In the current context, many cities have also aligned their urban design guidelines with the concept of walkable neighborhoods, as municipalities and developers see these models as offering higher urban quality of life and fostering a stronger sense of community (Noland et al., 2017; Abdelfattah et al., 2022a).
With this conceptual framework on the backdrop, the paper objective is to test a methodology to identify and evaluate the social, functional, and environmental features that can affect the attractiveness of a node of a major transit infrastructure, and, at the same time, what elements of the built environment are relevant to secure accessibility from and to the station. The analyses are centered around two distinct train station areas, facilitating a comparative assessment, and demonstrating the adaptability of the methodology across diverse contexts.
The evaluation criteria employed encompasses a wide range of indicators, from the social fabric to urban function density. This comprehensive approach serves a dual purpose: firstly, to pinpoint the strengths and weaknesses of the district surrounding the station, aiming to enhance both accessibility and the quality of public spaces; and secondly, to carry out a comparative examination of the metropolitan rail stations, offering insights for a TOD approach to urban planning.
Consequently, the research aims to address various questions, including but not limited to:

- What components of a place contribute to defining the attractiveness of a transit node within a complex urban environment?

- To what extent can both quantitative and qualitative indicators be harmonized/merged to describe the interaction between place and transit node?
- How can this knowledge be translated into practical policy guidelines?

The paper's structure unfolds as follows: In section 2, we contextualize Palermo and its mobility system, and examine several aspects that translate the relevance of the case study, such as its long struggle with the inefficiency of public transportation and a strong dependence on cars. Section 3 delves into the methodology and elucidates how we establish the catchment areas, define a comprehensive set of indicators aimed at measuring its attractiveness to city residents, and explain our process of indicator normalization to generate indexes that are well-suited for comparative analyses. In section 4, with the help of maps and tables derived from indexes and additional spatial analyses, we paint a detailed portrait of the case study areas, emphasizing the strengths and weaknesses around the attractiveness/accessibility nexus. Subsequently, we undertake a comparative analysis of the two case studies, which, despite their significant differences in socio-economic and built-environment characteristics, provide valuable insights for our research.

In the conclusive section we explore the potential of the applied methodology in the following two directions. On the one side, to expand research to other stations of the transit network, to allow a more systematic comparison among different realities and a wider set of policy guidelines for future urban/transport planning. On the other hand, the added value of the research will be identified under the light of the TOD and 15mC literature, with a focus on how these planning concepts can be integrated.

2. The development of Palermo urban railway network

Palermo is the capital of the Sicilian region and the fifth largest Italian city. According to the national census (Istat), its population in 2023 is 630,167. Despite a population decrease over the last decades towards the mid-sized neighboring towns, the core of the city is the daily destination of thousands of commuters due to the high density of amenities and functions. At the same time, the city’s attractiveness is rising due the growth of tourism and the regeneration process experienced since the 1990s, partly driven by national and European funding opportunities, and. The old town and the waterfront are two areas where such a change is clearer both from a physical and economic points of view (Vinci, 2019, 2022).

In this changing process, particularly interesting was the focus put by national and local authorities on the promotion of more sustainable mobility strategies and projects. This aspect is of key relevance once the city has been for decades a clear example of car dependent development model – listed for years among the most congested cities of Europe (Pishue, 2023) –, due to the chronic lack of efficient transit networks (Vinci & Di Dio, 2014) and the scarce provision and use of public transport (Laurenti & Trentin, 2023).

Change in the public mobility system took a significant step forward in 2002 after the approval of the ‘Integrated Plan for Mass Public Transport’. This process was later strengthened in 2013, with the approval of the first ‘General Urban Traffic Plan’, and in 2017 with the first ‘Sustainable Urban Mobility Plan’. These last instruments, particularly, made an attempt to reduce the prominence of cars in the city’s mobility system, by expanding the length of the bike lanes network, replacing the outdated bus fleet and, not least, by establishing a wide limited traffic zone coinciding with the Old town.

The city’s rail network received considerable attention with the above mentioned ‘Integrated Plan for Mass Public Transport’ that combined both new and previously planned projects. These included: (a) the redevelopment of the existing railway line into a metropolitan service (Railway bypass), which is the object of our investigation; (b) the redevelopment of an urban railway into an underground circle line (Railway loop); (c) three tram lines connecting the main rail stations to peripheral neighborhoods; and (d) a new subway line crossing the city from North to South. While this last intervention has been suspended, the creation of the tram lines was completed on schedule and the tram system will be further developed with additional lines whose construction is expected to start in 2024.

The implementation of the two interventions on the train network (Railway loop and Railway bypass) has faced several setbacks over time and part of the infrastructures are still under construction. The completion of the Railway loop – a single track underground line with 8 stops, for a total length of approximately 7 km –, after being delayed by financial issues of the contractor, is now expected in 2024 for a first section serving the city centre (Politeama station), while the full opening to service is scheduled in 2029.

The Rail bypass – 30 km of double track line that connect the airport to the central station – is largely in operation, but various financial and geological issues have also in this case slowed down the completion. As a result, three underground stations in the urban area are still under construction and the full layout will be completed only in 2026. This infrastructure, however, is still playing a key role in shifting the mobility behaviors in the metropolitan area, being widely used by commuters to reach the core city, and even by dwellers to move within the city and access the main urban functions.

The strategic function of the Rail bypass is finally recognized in various planning instruments under the responsibility of the municipal and metropolitan authorities. In the preparatory documents for the new Palermo land-use plan, the Rail bypass is seen as the backbone for a future urban development led by public transport. The Sustainable urban mobility plan (Sump) under preparation by the Palermo metropolitan authority (Città Metropolitana di Palermo) looks at the Rail bypass as among the main infrastructure to bridge the gaps between core and marginal areas existing within the city-region.

In the light of this rapidly changing mobility scenario, the following sections will address the question of the impact of the Rail bypass on the city's quality and organization, examining the many variables that can affect urban development around the railway station areas. To do so, the paper will concentrate on two complementary cases that are relevant to the conceptual framework adopted for the research: (a) the area of station 'Orleans', which is the busiest existing stop in the core city for the density of urban amenities around it, and (b) the area of station 'Lazio', under construction in the north edge of the city center, with a huge amount of rail users expected in the future.

3. Methodology

3.1 Definition of the catchment areas

In the scientific literature it is possible to find a myriad of views concerning the concepts of proximity and accessibility. Likewise, aspects such as the average travel times, distances and modes of transportation tend to take different paths to fulfil the different approaches taken. Given the purpose of this study, we focused on the areas that can be covered in approximately 7 to 8 minutes by walking. Most of all, the reasoning behind this choice relates directly to the specific context of Palermo and takes into account both spatial and behavioral factors, including: (a) 7-8-minute walking distance is usually an acceptable time to access/egress the train stations; (b) on average, it takes around 15 minutes to walk between consecutive nodes of the metropolitan rail line; and (c) the 7-8 minutes distance lays roughly in the median of 15 minutes and is halfway between 5 and 10 minutes.

We considered as the starting point the different train station exits and a default speed of 5 km/h. To delimit the catchment area of the node, the following procedure was respected:

- establish the extent of the walking network by calculating the "fastest route" using QGIS "Network Analysis - Service area" algorithm. The OpenStreetMaps roads were used as the "network" while it is publicly available information, therefore making the method more easily reproducible;
- carry out a preliminary verification, by comparing the resulting walkable network with isochrones calculated using several online API services, as for example Iso4App (see Fig.1, left);

- consider the extent of built environment affected by the station which is mostly linked to the qualitative aspects of the analysis, in particular to the availability and spatial distribution of city-level functions (see Fig.1, middle);
- overlay the limits of the Italian national statistics units which allows not only for a finer statistical analysis and the possibility to observe the changing trends between 2011 and 2021, but also to the replication of the method in other territorial contexts (see Fig.1, right).

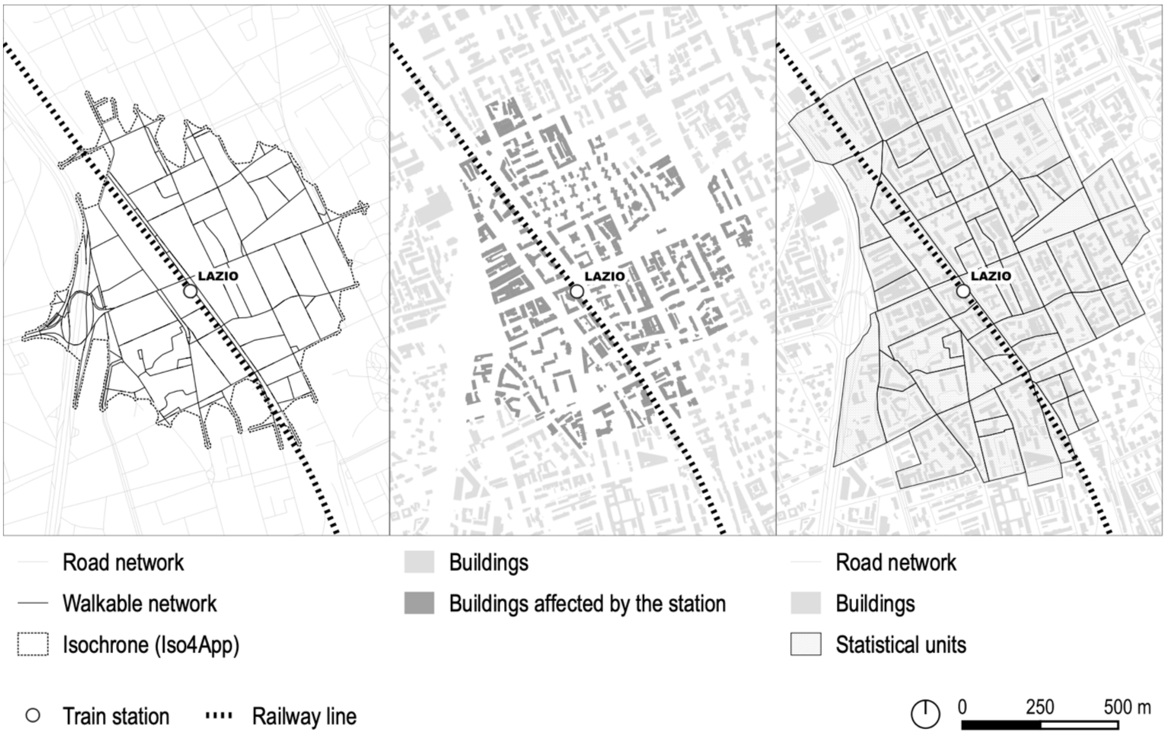

Fig.1 The main elements for the definition of the catchment area: the 7-8 minutes walking network (left), the built environment around the station (middle) and the statistical unit boundaries (right)

We finally established the catchment areas by hand drawing the boundaries of the isochrone (see Fig.2).

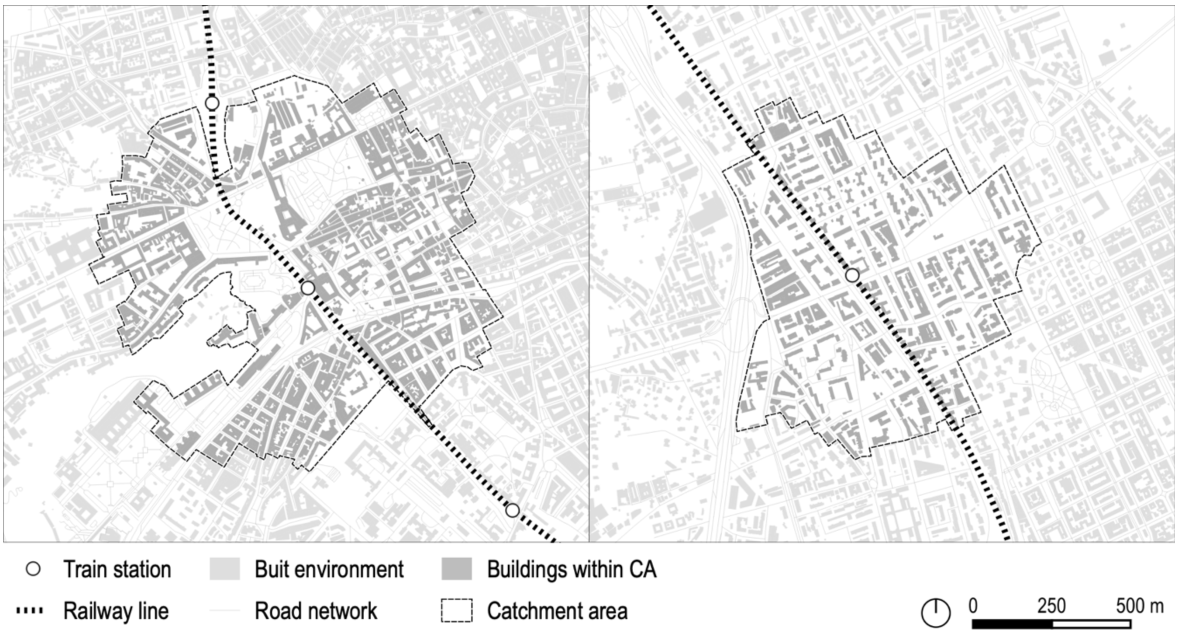

Fig.2 Two examples of the final hand drawn catchment area: the cases of 'Orleans' (left) and 'Lazio' (right)

3.2 Selection of the indicators to evaluate social, functional, and environmental features of the station's catchment areas

Given the qualitative and quantitative nature of our methodology, similarly to previous studies in literature (Bertolini, 1999; Lyu et al., 2020; Papagiannakis et al., 2021; Vale et al., 2018; Manfredini & Di Rosa, 2018), there isn't a single indicator that can comprehensively describe the various aspects of a case study area.

This was considered in the selection of qualitative and quantitative indicators (see Tab.2) that allow to characterize each catchment area in terms of density, functional diversity, mobility and accessibility, street quality, social diversity, digitalization, and flexibility.

Dimension	Data (input)	Indicator (output)
Social	Statistical data	Quantitative (numeric values)
Functional	Direct observation	Qualitative (mapping)
Environmental	Direct observation	Quantitative (index)

Tab.2 The three guiding dimensions of the quali-quantitative analysis, corresponding data sources and typology of indicators

Those indicators can be grouped as:

- Numerical indexes are mostly used to outline the socio-demographic profile, such as population density, old-age dependency ratio, education level, of station areas, along with providing insights into their housing conditions. These indicators are constructed using statistical data gathered at the level of census units, which enables detailed analysis and observation on a small scale and to easily compare results of each area;
- The functional analysis is generated through the mapping of specific function types and amenities that contribute to attractiveness of station areas' also for people from outside the district. The purpose of this analysis is to emphasize the density and distribution of city-level urban functions within the districts, as well as their spatial relation with to the road network and the train station. As emphasized by Bertolini in 1999, accessibility is about facilitating people's ability to engage in activities both at and around public transportation hubs. This involves considering the diversity of activities taking place near these nodes and the individuals who utilize them. These two aspects are vital for comprehending the concept of accessibility in the station areas.
- A hybrid approach is applied when assessing street quality analysis. In this case, a numerical index is created based on a combination of qualitative and quantitative evaluations of road conditions. This index is then used to create a spatial representation of the conditions that could impact accessibility to and from the stations.

Considering the walkability and accessibility objectives of the study, the assessment of street quality plays an important role in our analysis. As underlined by Southworth (2005), distance measurements to destinations alone do not sufficiently determine walkability. The critical factor lies in the quality of the pedestrian path network, as emphasized by Jaskiewicz (2001). Various aspects of the path network impact the probability of walking and can be enhanced through thoughtful design. Thus, in this analysis, we concentrate on a set of micro-scale indicators related to urban design attributes that affect pedestrian safety and comfort.

Indicators such as pedestrian-road ratio, vegetation, street lighting, slope, speed limit, traffic restrictions, road crossings, traffic calming elements that were individually graded, summed, and normalized to provide the final classification for each street. Each of these indicators undergoes an evaluation process informed by widely accepted standards.

Following a comprehensive examination of these indicators, a quality index is derived, which is then standardized on a scale from 0 to 1. This standardization enables the classification of streets within each catchment area. Consequently, priority zones can be identified to inform the development of policy guidelines and targeted actions.

Due to the quali-quantitative approach of our methodology, similarly to other works in literature (Bertolini, 1999; Papagiannakis et al., 2021; Vale et al., 2018) there is no unique indicator to describe the different features of the case study area. Indexes based on numerical values are mostly used to outline the socio-demographic profile of the district, as well as to describe its housing conditions. These types of indicators are based on statistical data at the level of census units, a factor that allow micro-scale observation and to easily compare results to other parts of the urban area.

The functional analysis is the result of mapping of selected types of functions and amenities that are relevant for the attractivity of the station area to city-users from outside the district. The aim of this analysis is highlighting the density and distribution of urban functions within the districts, as well as their spatial relation with the road network and the train station.

A hybrid approach, instead, is used in the analysis of the quality of streets. Here, a numerical index deriving from a quali-quantitative assessment of the road conditions are mapped to render a spatial representation of the condition that may affect accessibility from and to the station.

Considering walkability and accessibility objectives of the study, the evaluation of street quality assumes a pivotal role in our analysis. Given the limited control over determinants like land use and density patterns, our assessment focuses on a set of micro-scale indicators that belong to urban design attributes regarding safety and comfort of pedestrians (Southworth, 2005).

Indicators as pedestrian-road ratio, vegetation, street lighting, slope, speed limit, traffic restrictions, road crossings, traffic calming elements that were individually graded, summed, and normalized to provide the final classification for each street. Each of these indicators undergoes an evaluation process informed by widely accepted standards. Street-level analyses play a crucial role in connecting station areas with walkability, a pivotal component of the 15-Minute City concept.

Following a comprehensive examination of these indicators, a quality index is derived, which is then standardized on a scale from 0 to 1. This standardization enables the classification of streets within each catchment area. Consequently, priority zones can be identified to inform the development of policy guidelines and targeted actions.

4. The ‘Orleans’ and ‘Lazio’ stations: overview and analysis

The analysis carried out on this study focused on the train stations ‘Orleans’ and ‘Lazio’, both nodes of the Palermo metropolitan rail bypass. On the one hand, the ‘Orleans’ station is located at the southwestern border of the city’s old town (see Fig.3) and since its opening in 2001 has become one of the busiest train stations in the city. The main reason behind this is its location in the vicinity of many attractive points such as the university, the Sicilian Region presidency and Regional assembly buildings, as well as a children’s hospital and key cultural landmarks within the old town such as the cathedral or Orleans park (see Fig.4).

The surrounding built area of the ‘Orleans’ station area has been predominantly developed before the 19th century and includes a great share of land from the Old Town district ‘Albergaria’. This area, despite the historical presence of wealthy families and governmental/religious institutions has had a troubled history. In fact, as a consequence of the critical state of physical and social despair, during the 19th century the district was targeted by the Palermo’s first master plan (the so called 1885 ‘Piano Giarusso’). From then on, the area has been under a slow process of change divided equally between a rich heritage (that includes UNESCO World Heritage sites) and a challenging social context. In addition, other three more recent, and more residential districts are influenced by the station (such as the ‘Calatafimi’ or Oreto’ areas).

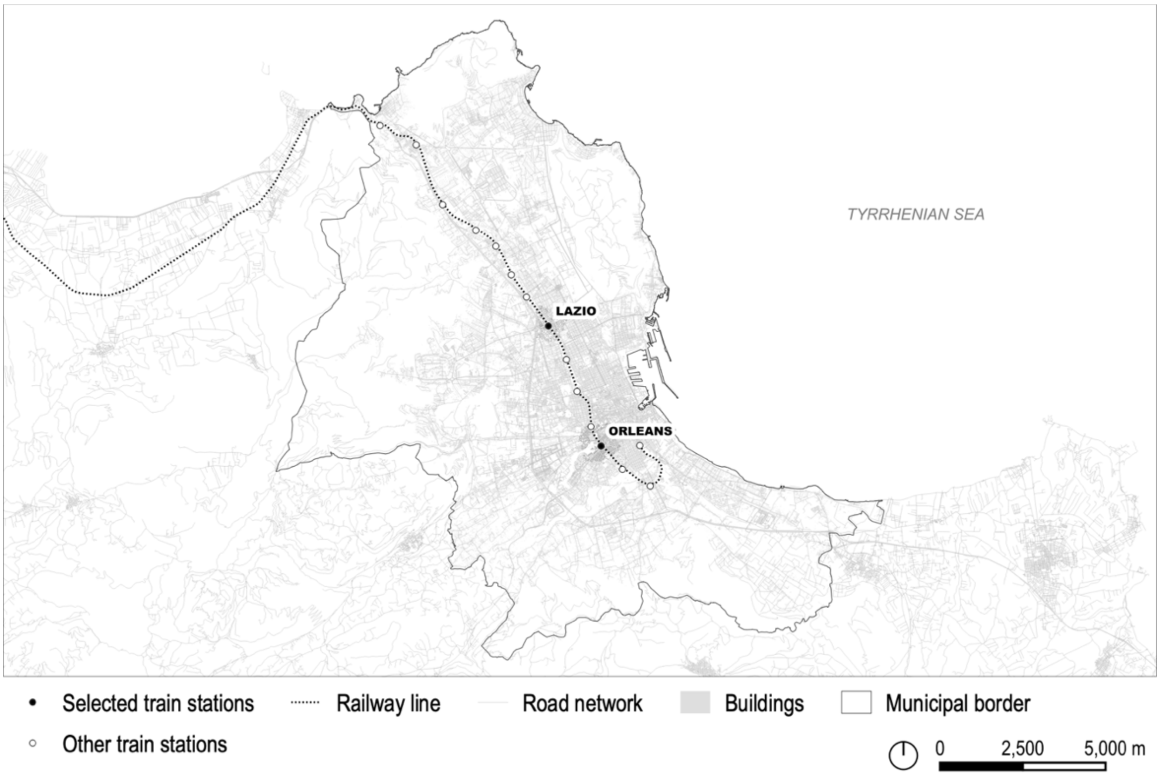

Fig.3 The location of the 'Orleans' and 'Lazio' train stations

On the other hand, the 'Lazio' station that is still under construction (expected cost of EUR 41 million), will be located towards the northern area of the city center (see also Fig.3), also known as the 'Libertà' district. The surroundings of the station saw a great expansion during the so called 'sacco di Palermo' (sack of Palermo) construction boom that took place during the second half of the 20th century. While the area is known to be mainly residential without the presence of any meaningful point of interest (see Fig.4a), the train station has the potential to increase the connectivity within the city and provide more proximity to people actually live in the area.

(a) (b)

Fig.4 Bird's eye view of the station areas. (a) The heterogenous, multi-functional context of 'Orleans' and (b) the dense, mono-functional, residential context of 'Lazio'

After selecting these two nodes of the railway system, the analytical methodology described in section 3 was used to define the stations' catchment areas (see Fig.5) and successively to start gathering the set of relevant quali-quantitative data which was then analyzed to describe and access the linkage between the stations, the neighboring road network and urban environment.

The aim is to portray the strengths, challenges, and opportunities in terms of attractivity/accessibility of two distinct areas of the city and ultimately provide support to political, strategic, and planning decisions that may improve the connectivity between the infrastructural nodes and its surrounding urban environment.

The reasoning behind the selection of these two stations was mainly linked with the assumption that by belonging to different urban contexts developed during separate periods, they would represent contrasting demographic backgrounds with distinct characteristics as regards urban functions. For the same reason it is expected that the outcomes of the study can cover a wider range of potential scenarios and therefore enrich the testing of the methodology.

Fig.5 The location and area of influence of the two station's catchment areas under analysis

The following sub sections introduce in greater detail the context of each station.

4.1 The 'Orleans' train station catchment area

The catchment area of the 'Orleans' train station has a total surface of 104 hectares and according to the 2021 statistical data, a total population of 15,178 inhabitants and a population density of around 145.5 inhabitants per hectare (3.67 times more than Palermo). Between 2011 and 2021 the area followed the city's demographic trend and lost population, around 1.5%. As regards diversity, there is a good gender balance, and of the total number of residents in the area 9.0% are foreigners (a value that increased more than 50% between 2011 and 2021). Furthermore, the ratio between the individuals older than 64 and those active was 28 for each 100, there is an employment rate like that of the city (41 employed for each 100 active people) and a lower percentage of adults with a higher education degree (only 15.9%).

Indicator	**Palermo**	**Orleans**	
	2021	**2021**	**2011-21**
Population density [pop/ha]	39.6	145.5	-1.5%
Male/Female ratio [for 100]	92	99	+5.1%
Old-age dependency ratio [for 100]	35	28	+10.7%
Share of non-national residents [%]	3.8	9.0	+55.3%
Share of active population [%]	63.7	65.7	-2.1%
Adult education level: higher degree [%]	20.3	15.9	+32.1%
Employed/Active population ratio [for 100]	46	41	+5.4%

Tab.3 Set of socio-demographic indicators the ' Orleans' train station catchment area

As mentioned above the 'Orleans' train station catchment area includes a relevant slice of the old town urban fabric. For this reason, approximately 85% of the buildings in the catchment area were built before 1960. Regarding the characteristics of the built environment, although 56.2% of all 1173 housing buildings presented in 2011 a bad state of conservation, their occupancy rate was very high, at 92.8%. Moreover, the housing density is around 80.5 houses per hectare which reflects a very consolidated urban context, and 26.9% of the 8396 houses are vacant. In comparison to the city there are 1.87 times more non-occupied houses in the 'Orleans' area.

Indicator	**Palermo**	**Orleans**
	2011	**2011**
Housing density [houses/ha]	17.8	80.5
Vacant houses [% over total]	14.3	26.9
Used buildings [% over total]	96.1	92.8
Buildings constructed pre-1960 [% over total]	47.4	84.9
Buildings in poor state of conservation [% over total]	26.6	56.2

Tab.4 Set of indicators regarding housing and the built environment of the 'Orleans' train station catchment area

With respect to the daily commuting habits of the residents, in 2011 the great majority travelled within the city (96.8%) and 3.2% travels towards neighboring towns. In addition to the train station, the current public transport system available in the area counts on 28 bus stops and 30 bus routes. This shows that connectivity in the area shall be seen an aspect that cannot be disregarded.

The observation of the availability and spatial distribution of city-level functions in the 'Orleans' catchment area shows that it is possible to reach many attractivity nodes (see Fig.6, left) including:

- Education (universities, high schools);
- Military/law enforcement (police headquarters, barracks);
- Government (offices of Sicilian Region Presidency and Regional Assembly); and
- Health (children's hospital).

This indicates the high potential of the station in terms of users, both residents and outsiders. At the same time, it highlights the importance of ensuring adequate connections around the node, that can be achieved through a livable network of pedestrian routes and public spaces.
However, the majority of the streets in the catchment area present low-quality standards for pedestrians as they don't ensure the most adequate walkability conditions. The pedestrian-road width ratio is typically lower than 30% and therefore not suitable for 2-3 people to pass one another or to walk in groups (Southworth, 2005). Regarding comfort, lighting is available in all streets, however there are few streets with speed limit for vehicles that negatively affects the walking pleasure and safety. On the contrary, traffic restrictions are available in a comparatively higher number of streets. This is because the catchment area comprises part of the 'traffic limited zone' of the historic center. Vegetation is mostly scarce, except for some certain arterial roads and green areas (public gardens and squares). There aren't slope variations that pose issues for walking.,
In terms of shared mobility there are two bike sharing stalls which could benefit from being closer to the station and it is possible to reach three car-sharing areas. When it comes to pedestrian safety, the catchment area exhibits notably low quality due to its poor state of infrastructure, primarily attributed to its historical significance. Furthermore, the low pedestrian index, which represents the ratio of pedestrian pathways to the total street width, indicates a lack of pedestrian comfort. This is particularly pronounced in the historical center where the streets are often too narrow to ensure safe pedestrian movement alongside vehicular traffic.

4.2 The 'Lazio' train station catchment area

The catchment area of the 'Lazio' train station has a total surface of 69 hectares and according to the 2021 statistical data, a total population of 15,010 inhabitants and a population density of around 201.4 inhabitants per hectare (5.08 times more than Palermo). Between 2011 and 2021 the area followed the city's demographic trend and lost population, around 2.9%. As regards diversity, there is a decent gender balance, and of the total number of residents in the area only 2.2% are foreigners (a value that increased significantly between 2011 and 2021). Furthermore, the ratio between the individuals older than 64 and those active was 45 for each 100, there is an employment rate higher than the rest of the city (58 employed for each 100 active residents) and a considerable percentage of adults with a higher education degree (43.1%).

Indicator	**Palermo**	**Lazio**	
	2021	**2021**	**2011-21**
Population density [pop/ha]	39.6	201.4	-2.9%
Male/Female ratio [for 100]	92	83	+2.6%
Old-age dependency ratio [for 100]	35	45	+11.4%
Share of non-national residents [%]	3.8	2.2	+60.0%
Share of active population [%]	63.7	61.0	-2.4%
Adult education level: higher degree [%]	20.3	43.1	+12.5%
Employed/Active population ratio [for 100]	46	58	-0.9%

Tab.5 Set of socio-demographic indicators the 'Lazio' train station catchment area

As mentioned above the 'Lazio' train station catchment area corresponds to an area developed mainly during the second half of the 19th century. For this reason, approximately only around 26,5% of the buildings in the catchment area were built before 1960. Regarding the characteristics of the built environment, although 56.2% of all 1173 housing buildings presented in 2011 a bad state of conservation, their occupancy rate was very high, at 92.8%. Moreover, the housing density is very high (around 93.3 houses per hectare) which reflects a urban context characterized by tall residential buildings where only 7.1% of the 6952 houses are vacant. In comparison to the city there are roughly half non-occupied houses in the 'Lazio' area.

Indicator	Palermo 2011	Lazio 2011
Housing density [houses/ha]	17.8	93.3
Vacant houses [% over total]	14.3	7.1
Used buildings [% over total]	96.1	98.5
Buildings constructed pre-1960 [% over total]	47.4	26.5
Buildings in poor state of conservation [% over total]	26.6	16.6

Tab.6 Set of indicators regarding housing and the built environment of the 'Orleans' train station catchment area

With respect to the daily commuting habits of the residents, in 2011 the great majority travelled within the city (96.5 %) and 3.5% travels towards neighboring towns. In addition to the train station, the current public transport system available in the area counts on 20 bus stops and 25 bus routes.
The observation of the availability and spatial distribution of city-level functions in the catchment area shows a predominance of residential buildings and very few attractive nodes. This indicates the high potential of the station in terms of the residents and a very low potential for outside users.
In general, the streets within the 'Lazio' station area are notably pedestrian-friendly. Thanks to its densely populated urban layout, the streets are typically quiet and well-maintained. Larger streets accommodating various functions, including commercial and personal services, exhibit higher traffic density compared to the rest of the streets.
While the overall quality of streets and public spaces in the 'Lazio' station area remains satisfactory, and the width of sidewalks largely meets the minimum requirements for safe pedestrian movement, there are critical issues that significantly impact pedestrian mobility in the area. Particularly in narrow streets, the practice of parking on both sides encroaches upon the sidewalks, resulting in a safety concern. This issue is compounded by the fact that this area falls outside the traffic-limited zone, making parking a primary challenge for pedestrian flow.

5. Insights from the analysis and discussion of the results

The two catchment areas under analysis are associated with two different urban contexts with particularities that range from the characteristics and quality of the built environment, the socio-economic fabric, as well as the functional role within the urban system.
When we delve into the socio-economic fabric of both train station catchment areas emerge not only some similarities but also significant differences (see Tab.7). For instance, both catchment areas show an equivalent number of inhabitants, although the population density in 'Lazio' is higher due to the large presence of residential plots. Likewise, both areas have a similar gender balance among the residents, but 'Orleans' has a concentration of non-national residents four times higher than 'Lazio'. This aspect gains more significance when we look at the notably lower percentage of residents of 'Orleans' that hold a higher academic degree, and in contrast the number from 'Lazio' which is almost the double of the city. Furthermore, the level of employed residents in 'Lazio' is 1.4 times higher than those of 'Orleans', which underly the socio-economic unbalances between the two demographic contexts.
It's important to highlight that 'Orleans' faces a significant presence of buildings in poor condition and vacant structures, emphasizing the potential for enhancement. At the same time, while its central location contributes to the diversity in uses and functions that attract more people from outside, the accessibility of local residents should also be considered.
In contrast, 'Lazio' remains a mono-functional area dominated by housing or local-level services. When considered within the framework of the concepts that there could be different reasoning for households to prefer private mobility modes, such as land use (Kenworthy & Laube, 1999), car ownership (Langer et al.,

2023), urban infrastructure (Wang et al., 2018) and built environment (Cao et al., 2023), along with insights from other studies (Calthorpe, 1993; Moreno et al., 2021; Papagiannakis et al., 2020; Pozoukidou & Angelidou, 2022; Pratt et al., 2007) which highlight the importance of social and functional diversity for both concepts, the indices suggest that Lazio may be following a more car-centric development model.

Indicator	Palermo	Orleans	Lazio
Population density [pop/ha]	39.6	145.5	201.4
Male/Female ratio [for 100]	92	99	83
Old-age dependency ratio [for 100]	35	28	45
Share of non-national residents [%]	3.8	9.0	2.2
Share of active population [%]	63.7	65.7	61.0
Adult education level: higher degree [%]	20.3	15.9	43.1
Employed/Active population ratio [for 100]	46	41	58

Tab.7 Key socio-economic indicators of the 'Orleans' and 'Lazio' catchment areas in 2021

But another point to keep in mind is that since not all the station areas could have same land use or socio-demographic structure, there are different types of TOD models which are suitable for different context (Pratt et al., 2007).

It is also needed to stress the importance of the (bad) quality of the pedestrian infrastructures and the role it can play in providing accessibility and increasing proximity. For instance, the 'Orleans' catchment area represents good candidate case where the implementation of the right set of actions could help increase accessibility among a more fragile social context. By the same token, 'Lazio' is a prime candidate for increasing proximity through an improved public transportation access and the enhancement of pedestrian infrastructure. While both cases provide valuable testing environments for the 15-Minute City concept.

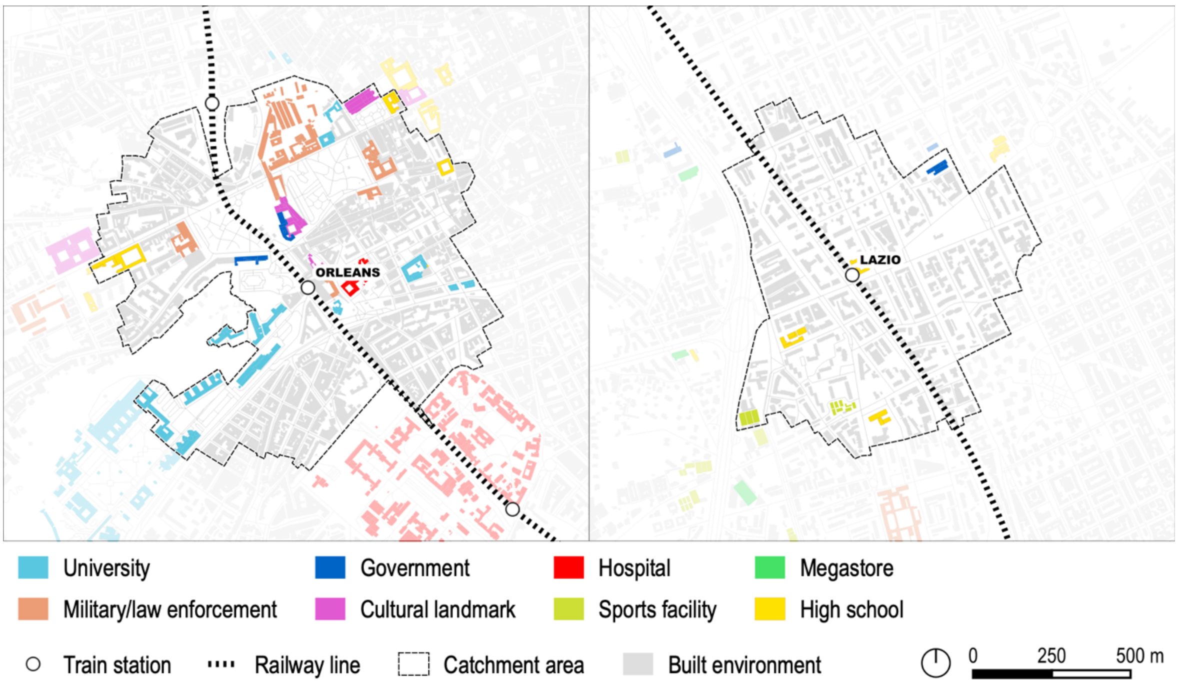

Fig.6 The distribution of city-level functions of the 'Orleans' and 'Lazio' catchment areas

When we examine both station areas' street quality (see Fig.7), 'Orleans' is characterized by a more organic urban layout with narrow streets rooted in its historical heritage. In contrast, 'Lazio' features a more planned layout with wider streets. This variation results in a higher pedestrian-road ratio in 'Lazio', where sidewalks are typically separate from the road, in comparison to 'Orleans', although the difference is not substantial. The average pedestrian index for 'Lazio' stands at 0.32, while in 'Orleans', it is 0.22.

The most significant distinction lies in the prevalence of road crossings. In 'Lazio', 74% of streets feature road crossings, whereas in 'Orleans', this figure is 37%. Notably, the average street width in 'Orleans' is approximately 12 meters, while in 'Lazio', it spans 18 meters.

Another notable contrast between these two station areas is the presence of street vegetation. Despite having parks and squares within the station area, 'Orleans' records an average vegetation index of 0.22 on a scale from 0 to 1. Conversely, the second station area boasts an average vegetation index of 0.48, providing ample shading and an enjoyable walking experience for pedestrians even if there is a lack of high-quality public spaces such as parks and gardens.

In summary, the 'Lazio' station area boasts an average street quality index of 0.38, while the 'Orleans' station area records a street quality index of 0.27. This indicates that both stations lack distinctly high-quality streets for pedestrian mobility. However, it is evident that the 'Lazio' station area exhibits superior infrastructure and overall better quality.

Several additional factors influence walkability such as the presence of litter in certain streets within both station areas and poorly designed bike paths, often compelling pedestrians to share the road with vehicular traffic and decrease the safety of pedestrians.

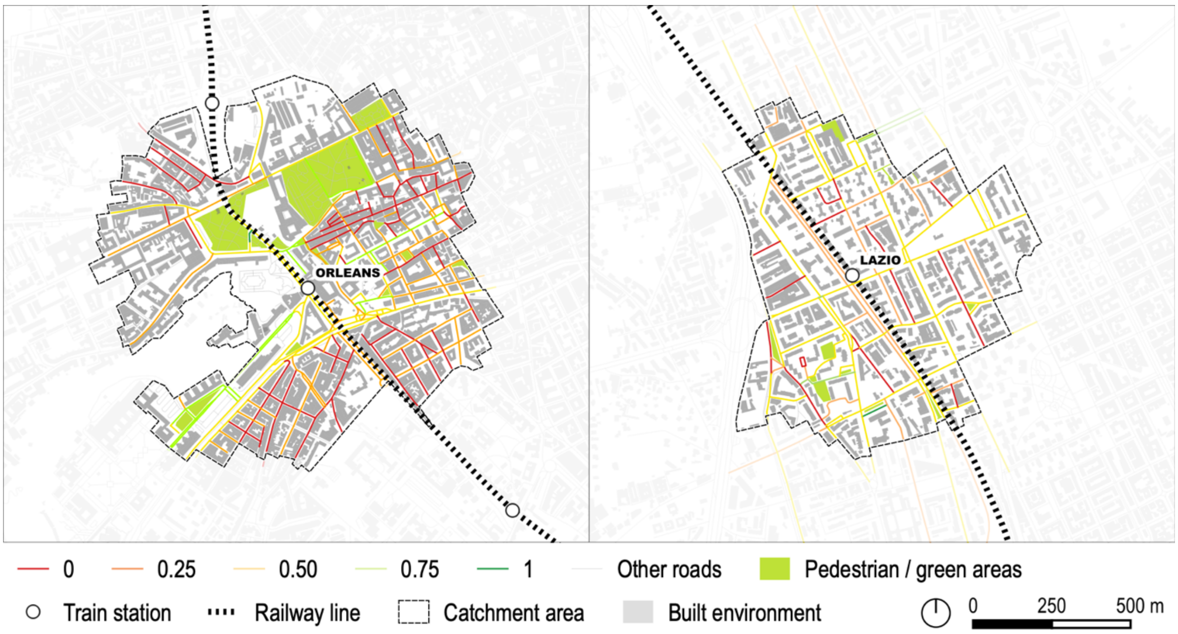

Fig.7 The street quality analysis of the 'Orleans' and 'Lazio' catchment areas

6. Conclusion

The added value of the research presented in this paper is twofold. On the one side, it provides the first integrated analysis of the city-transport interactions in a city — Palermo — characterized for a long-underdeveloped planning system in both the transport and land-use sectors. In this context, the work seeks to improve knowledge on the impact of existing and future mobility systems on the quality and organization of urban development, with the wish that new methodologies could be embedded within future policy-making. While being built on upon existing methods in literature (Bertolini, 1999; Papagiannakis, 2021; Vale et al., 2018), the analysis provides an original approach to combine qualitative and quantitative data, and creating measurable indicators from a wide range of sources including geographical data, on-site observation, statistical information, among others.

On the other side, by connecting the used indicators to the founding principles of the TOD and 15mC paradigms, the study attempts to explore the synergies between the two planning concepts in an operational perspective. The theoretical assumption of the work is that the two concepts are not only compatible, but also that should be integrated as they cover essential feature of sustainable urban development (e.g., long-range accessibility, quality of public space, mixed-use, etc.). From this point of view, the areas around the transport nodes are seen as the contexts of complex interactions between different drivers and domains, including place, people, functions, quality of the environment, accessibility, etc. All these features are, to a different extent, very relevant to both the TOD and 15mC concepts and data are used to describe the points of strength and weakness that could be addressed in a planning perspective.

The next development of the research, thus, will consist in the application of the methodology to a wider set of station-areas of the metropolitan rail bypass with diverse social, functional, and physical structure, with the perspective to expand the analysis to all the transport networks nodes in a city-wide dimension. This will allow policy makers to have a comprehensive assessment of the needs and potential of each station district in the metropolitan area in order to, for instance, densify housing and/or certain types of services, if necessary; to improve the condition of public space to ease the access to and from the transport nodes; to develop secondary mobility systems (e.g. buses or shared mobility services) to facilitate the first/last mile connections to the rail network, etc.

At the same time, the research could be further developed by expanding the set of variables used to represent the station areas profiles. For instance, additional pedestrian safety and comfort aspects shall be considered to extend the scope of the street analysis, the impact of parking behaviors and other physical obstacles on which may have an impact on pedestrian movement, a spatial representation of mobility flows and traffic congestion around the stations, just to mention a few. This adjustment will improve the usefulness of the analysis to meet the needs a wider range of city users (including fragile people), as well as helping to adapt the methodology to different urban contexts.

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Assessing mobility in sustainable urban regeneration. The GBC Quartieri application to Le Albere neighbourhood in Trento

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Abstract

In order to minimise the negative impacts of new districts, mobility analysis plays a crucial role. Indeed, urban expansion may lead to increased car use to access basic services. Establishing interconnections between novel localities, parking spaces, public transportation routes, limiting the heat island phenomenon and instituting renewable energy sources are indispensable for realising sustainable design. This approach may mitigate the adverse impacts of informal urban expansion and foster condensed, pedestrian-oriented neighbourhoods that encourage cycling and walking. In this context, international protocols can provide valuable guidance during the planning and upkeep phases by furnishing analysis and design recommendations. In this paper, starting with an analysis of the GBC Quartieri energy and environmental sustainability protocol on an urban scale, a method for evaluating the protocol's responses to known mobility-related critical issues was prepared and used to evaluate the case study Trento Le Albere project. This showed that almost 50 per cent of the internal credits and prerequisites are focused on mobility, including the smart location of the new neighbourhood and the implementation of bicycle mobility, interchange points and shaded streets. These solutions were evaluated based on their relationships with critical mobility issues, providing a comprehensive solution that focuses chiefly on the connection system, accessibility and usability performance, control, and climatic impact.

Keywords

Sustainable mobility; GBC Quartieri protocol; Le Albere project.

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1. Introduction

As is widely acknowledged, cities consume 75% of the world's resources despite covering only 2% of the earth's surface (Mersal, 2017). Furthermore, cities house the majority of the world's population, with 2.3 billion individuals currently residing in urban areas (UN-Habitat, 2020), and are a significant driver of economic growth (Allam & Jones, 2021). According to the United Nations Sustainable Development Goals 2022 Report, over 50 per cent of the world's population currently lives in cities. By 2050, an estimated 70% of the world's population will reside in urban areas. Metropolitan environments drive economic growth and produce over 80% of the global GDP. Unfortunately, they also generate over 70% of global greenhouse gas emissions, contributing to noise pollution and creating heat islands while encouraging sedentary behaviour among their inhabitants (Nieuwenhuijsen & Khreis, 2019). Careful urban planning and management can support sustainable development and foster prosperous, inclusive communities (United Nations, 2022). Europe is the second most urbanised region, with a rate of 70%; North and South America surpass this with rates of 80% (Economist Intelligence Unit, 2012). The European Union (European Commission, 2014) and the United Nations (United Nations, 2015) have established climate targets and energy projects to tackle existing challenges. Additionally, the European Union's 'Cities of the Future' report highlights cities as hotspots for issues, but also as potential solutions.

Sustainable development and environmental considerations are crucial in effectively managing urban growth, offering scope for innovation, progress and change. Cities should review their approach to urban space, enhancing its quality and making urban transformation more viable. This requires the amalgamation of environmental sustainability objectives with those of urban planning, governance, economics and social inclusion (Gandolfi et al., 2014). As described in Goal 11, 'Sustainable Cities and Communities', it is necessary to convert urban centres into environmentally-friendly cities that offer inhabitants convenient housing, essential services, and reasonable, secure, and efficient transport choices. To achieve this, the proposed strategies include improvement of the local public transport system and a focus on groups that are more vulnerable, such as women, children, individuals with disabilities, and others (UN General Assembly, 2015). Moreover, it is imperative that cities implement strategies to mitigate their adverse effects on the environment. This can be achieved by advocating for the creation of secure and accessible green spaces and public areas whilst simultaneously prioritising cultural preservation (United Nations, n.d.).

In the field of mobility, the Global Mobility Report 2017 (Sustainable Mobility for All, 2017) illustrates that transportation is bound to expand as an increasing number of individuals and goods navigate urban centres. By 2030, it is predicted that transportation will escalate by 50% compared to 2015, causing the number of vehicles on the road to reach a total of 1.2 billion, which is twice that of the current amount. Given text is already adhering to the given principles. Therefore, here's the answer: Considering that the choice of today's mobility system determines how the territories of the future will develop, meeting the growing demand for mobility, if planned as done so far, has the potential to contribute to environmental degradation and increase air pollution levels in cities, as well as amplify the effects of climate change. The impact of mobility on our society cannot be underestimated, particularly with regard to our health and well-being. Issues such as greenhouse gas emissions, pollution of air, soil and water, along with traffic accidents, congestion and loss of biodiversity (European Commission, 2021) are just some of the costs we must consider.

Advocating sustainable mobility is crucial, as the European Council has defined in their European strategy, to make certain that transportation systems fulfil the economic, social, and environmental needs of society while minimising undesirable impacts on the economy, society, and the environment (Council of European Union, 2006). Furthermore, research indicates that social and economic impacts must be taken into account, in addition to environmental factors alone (Gallo & Marinelli, 2020). The development of this concept originates from the Aalborg Charter and its ten principles (1994), proceeding to the Leipzig Charter, which included the aim for integrated urban development and governance in 2007, and culminating with the contemporary approach to urban mobility policies exemplified by the Sustainable Urban Mobility Plans (SUMP) (Vittadini, 2019).

To achieve a concrete improvement in sustainable mobility, it is essential to promote the adoption of new technologies and engage citizens to prefer environmentally friendly modes of transportation. This can be done with the participation of stakeholders who can contribute their ideas and expertise to the project process and thereby modify their mobility habits (Spadaro et al., 2023). The choice of travel mode (means, routes) is influenced by factors surrounding the existing mobility system and the perception of its inhabitants. Merely creating useful infrastructures is insufficient; the correct perception of their accessibility must also be established (Larco et al., 2012).

The implemented strategies incorporate incentives for employing environmentally friendly modes of transportation, measures to encourage public participation, communication, and public awareness programs. These efforts aim to influence the behavioural patterns of individuals towards alternative and sustainable mobility solutions (Ministero delle Infrastrutture e dei Trasporti, 2022).

It is crucial to evaluate current transport systems objectively with priority interventions in urban planning, both in Italy and Europe. Development and implementation of policies with site-specific and place-based approaches (Privitera, 2023) are necessary. The aim is not to prohibit car use, but to encourage the population to consider alternative modes of transport as primary choices (Banister, 2008). The pandemic has emphasised the necessity of examining current transport systems for their resilience and equitable nature (Beck & Hensher, 2020). A distinct shift in collective public transport usage is required as it contradicts the social distancing paradigm, causing users to resort to private, motorised transportation means (Privitera, 2023).

The primary concerns with mobility in urban regeneration comprise insufficient socially and environmentally optimal connection systems, inadequate accessibility and usability, ineffective management of climatic factors, noise, light and air pollution due to the use of private vehicles (Radogna, 2015), an outdated mobility system with a private car focus, and disorganised transport systems in urban centres (Francini et al., 2019).

In this context, sustainability protocols can assist by objectively evaluating individual buildings and improving their inherent qualities and connection with the environment. This encourages conscientious management of buildings within their context. These international systems have evolved to include neighbourhood, community and city-wide scales over time, enhancing overall sustainability; its are voluntary, widespread throughout the world, and enable a sustainability comparison using quantitative and/or qualitative parameters. Although addressed differently, transport and mobility are ubiquitous themes in all urban classification systems (Privitera, 2023).

Building on these reflections, this article aims to establish an assessment process that highlights effective strategies to tackle mobility-related issues and their interrelations by scrutinising the Italian GBC Neighbourhoods protocol. Indeed, one problem with sustainable redevelopment projects or sustainable neighborhood redesign interventions, in this case particularly in the context of sustainable mobility, is the difficulty of measuring their effectiveness in order to make informed decisions. Protocols analysis could be a useful tool in addressing this issue.

The text presents a structured contribution that begins with an exposition of the situation related to sustainability protocols on an urban scale and their connection with sustainable mobility. The GBC Quartieri protocol is given particular attention. Following this, a methodological proposal is presented to evaluate the sustainable mobility in a project. This is achieved by comparing critical issues related to mobility with the solutions proposed by the protocol. Finally, this method is used to evaluate a case study. In fact, by assessing the connectivity and accessibility of the Trento Le Albere neighbourhood with the city centre and main urban services, the evaluation of the project's success in meeting expectations was made possible. Although it has not been certified as a neighbourhood, it was designed prior to the development of the urban-scale rating systems mentioned earlier. The expansion of the former Michelin site in Trento is regarded as a significant urban intervention in the northern region of Italy, encompassing roughly 11 hectares of land. The objective of employing over 300,000 cubic metres of ecologically sustainable technologies is to establish a novel residential district in the city.

2. Materials and methods

Since the introduction of the Japanese CASBEE Urban Development in 2006, several urban development rating systems have been created, including the British BREEAM Communities, the American LEED Neighbourhoods, and the Australian Green Star for communities. Additionally, the Italian GBC Quartieri was established in 2015. In 2016, the focus expanded to assessing entire cities, as the USGBC introduced LEED for Cities and Communities. The aforementioned led to the adoption of the digital platform ARC, which facilitates the ongoing monitoring and evaluation of the sustainability of the entire construction industry over time employing regularly updated indicators (Dall'O', 2021). In terms of scale, protocols distinguish between those covering larger spatial areas (neighbourhoods or districts) such as GBC Neighbourhoods and LEED for Neighbourhoods, and those that have established sustainability assessment and ranking frameworks at city and/or community level such as BREEAM Communities, STAR and LEED for Cities and Communities (GBC Italia, 2021).

The assessment mechanisms are voluntary and enable the comparison of various projects using weighted indicators and an evaluation grid (Yamany et al., 2016). The thorough certification procedure entails the third-party collection and evaluation of relevant documents. In general, the focus is to monitor ongoing sustainability trends by conducting self-assessments of policy effectiveness related to one or more sustainability objectives. This also involves comparing sustainable performance by incentivising virtuous emulative and competitive attitudes, and evaluating sustainability performance with reference to benchmarks to recognise certain levels achieved, particularly for territorial marketing and/or communication strategies (GBC Italia, 2021).

The protocols are closely linked to the territorial context of origin and rely on local legislation, rules, and cultural and social aspects (Francini et al., 2019). Various scientific contributions have adopted these protocols for different purposes. These range from a qualitative comparison of the energy and environmental sustainability of a building and urban construction project (del Bo, 2020) to the creation of a new definition of a sustainable neighbourhood (Codispoti, 2021). They also include an internal analysis of these tools to understand whether they can help a new settlement to become a truly more sustainable area that considers the needs of the society of the future (Papa et al., 2016), or whether they can be reused for the realisation of new protocols specific to new types of settlement (Volpatti et al., 2024). Criticism of urban rating systems includes concerns about the selection of internal indicators, which are subject to prior settings. Nevertheless, these constraints are overcome through continuous review and periodic evaluation of the system.

The study seeks to assess the GBC Quartieri protocol, which originated in Italy and drew inspiration from LEED for Neighborhood, but was adapted to the Italian setting. This tool is voluntary and market-driven, serving as both a guideline and assessment mechanism based on consensus. The aim is to optimise the utilisation of natural resources, endorse regenerative and restorative techniques, minimise negative repercussions to the environment and human health, and furnish superior indoor surroundings for edifice occupants. Every GBC and LEED rating system is arranged into two sections, prerequisites – the mandatory component, and credits – the section where points are awarded. Depending on the number of points achieved, a project attains a rating level of Certified (40-49), Silver (50-59), Gold (60-79) or Platinum (over 80) (Boschetto et al., 2022).

This standard offers a framework to aid planners, local authorities, developers, and investors with the integration and evaluation of sustainable design in the general planning of novel communities and regeneration schemes (Green Building Council Italia, 2023). The protocol was exclusively utilized for Euromilano's UpTown project in Italy, achieving the Gold level, a smart district situated in an area that encompasses the renovated Cascina Merlata, which is currently a service hub for citizens, in the north-west area of Milan. The new district covers an area of 900,000 square metres, with 300,000 square metres designated as parkland, and designed to accommodate 12,000 residents. The project aims to promote sustainable mobility, social housing and neighbourhood services. Additionally, there will be a new railway station and improved public mobility (Euromilano S.p.A., n.d.).

GBC Quartieri comprises three main categories:

- *Smart Location and Linkage*, which incorporates measures to reduce negative environmental impact through functional mixite, appropriate access to public transportation, and utilization of existing districts. The selection of such areas facilitates a decrease in soil consumption and diminishes the requirement for constructing novel infrastructure. Consequently, this lowers the extension of impenetrable surfaces, which amplifies the likelihood of detrimental phenomena associated with rainwater management;
- *Neighborhood Pattern and Design* scrutinizes links, amenities, and the network of connections, thereby appraising infrastructure efficacy and urban densification. Community involvement in the design and planning process is emphasized in this section;
- *Green Infrastructure and Buildings* where the the objective is to reduce environmental impacts associated with construction, maintenance, and long-term management (Green Building Council Italia, 2015).

Regarding mobility and transport, the protocol includes numerous requirements and credits. Specifically:

- it recommends promoting public transportation;
- It is recommended to restrict the expansion of urban areas to decrease travel distances and frequency;
- There should be an emphasis on promoting cycling and walking by developing safe, visually appealing, and comfortable routes;
- It is also important to encourage community connections and internal connections for large-scale urban and territorial projects;
- To prevent soil consumption and related rainwater runoff, there should be a reduction in the development of car parking facilities;
- Incorporate recycled and reclaimed materials throughout the project;
- Utilise innovative systems to minimise light pollution.

3. Methodological proposal

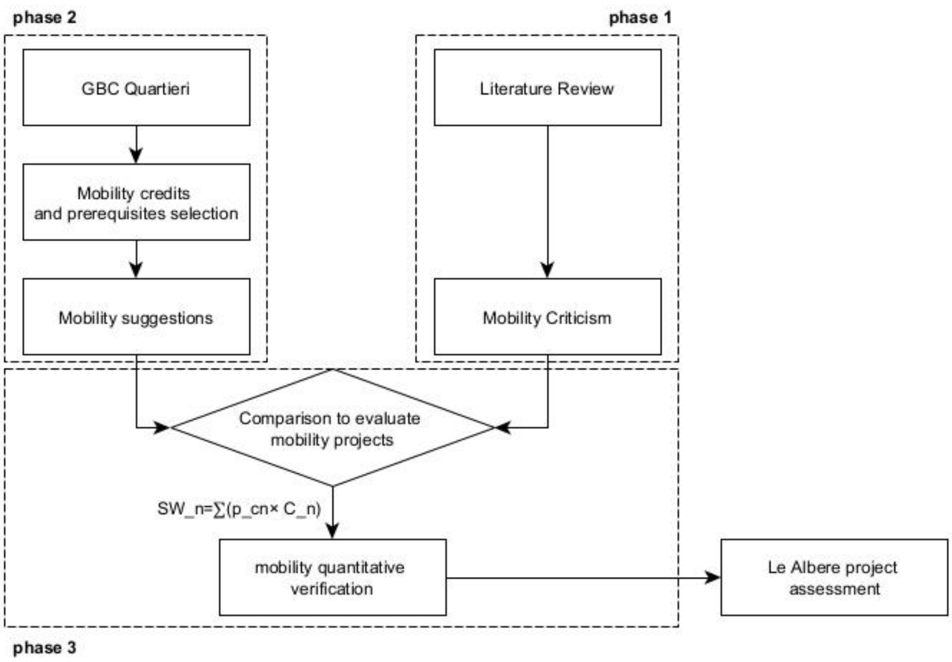

Fig.1 Flowchart of the proposed methodology

To quantitatively evaluate sustainable mobility in a project, the proposed methodology involves three phases: first, collecting critical issues related to the topic, as already exposed in the introductory section; second, analyzing the GBC Neighborhoods protocol parameters connected to sustainable mobility; and finally, comparing the results of the two phases using a weighting system. Le Albere di Trento can be evaluated upon completion using this method. The flowchart mentioned earlier can be seen in the following Fig.1.
From analysing the energy and environmental sustainability protocol at the urban scale of GBC Quartieri (Tab.1), it can be observed that a significant proportion of the credits and internal prerequisites pertain to mobility. These include the strategic placement of the new neighbourhood, cycling infrastructure, interchange points and shaded streets.

	Smart Location & Linkage		
Code	**Description**	**min points**	**max points**
LCS_p1	Smart Location	X	
LCS_c1	Preferred Locations	1	10
LCS_c3	Access to Quality Transit	1	7
LCS_c4	Bicycle Facilities	1	2
LCS_c5	Housing and Jobs Proximity	1	3
	Neighborhood Pattern & Design		
Code	**Description**	**min points**	**max points**
OPQ_p1	Walkable Streets	X	
OPQ_p2	Compact Development	X	
OPQ_p3	Connected and Open Community	X	
OPQ_c1	Walkable Streets	1	9
OPQ_c2	Compact Development	1	6
OPQ_c3	Mixed-Use Neighborhoods	1	4
OPQ_c5	Reduced Parking Footprint	1	1
OPQ_c6	Connected and Open Community	1	2
OPQ_c7	Transit Facilities	1	1
OPQ_c8	Transportation Demand Management	1	2
OPQ_c14	Tree-Lined and Shaded Streetscapes	1	2
	Green Infrastructure & Buildings		
Code	**Description**	**min points**	**max points**
IES_c15	Recycled and Reused Infrastructure	1	1
IES_c17	Light Pollution Reduction	1	1

Tab.1 Selection of prerequisites and credits in GBC Quartieri regarding mobility: the lighter blue principles are indirectly related, while the darker blue principles are closely related

	Smart Location & Linkage		**Neighborhood Pattern & Design**		**Green Infrastructure & Buildings**	
	min points	max points	min points	max points	min points	max points
mobility connected	3	19	2	10	2	2
mobility closed connected	1	3	6	17	0	0
mobility	4	22	8	27	2	2
total	9	28	16	43	17	29
% mobility	44%	79%	50%	63%	12%	7%

Tab.2 Sustainable mobility weighting in GBC Quartieri is divided into internal main categories. Lighter blue principles are indirectly connected with mobility, while darker blue principles are closely connected with mobility. This is in accordance with the previous table

In fact, mobility-related sustainability holds significant importance within the protocol, particularly for the Smart Location & Linkage and Neighbourhood Pattern & Design categories, evidenced by high percentage values in Tab.2. Evaluating the protocol holistically, mobility-related credits account for between 33% (minimum points) and 51% (maximum points) of achievable scores.In this analysis, both the requirements and incentives that are directly related to sustainable mobility were considered, as well as those that indirectly support it, such as the compact development of the neighbourhood and adequate street lighting.

The issue of transportation is not unique to GBC Quartieri, but is a shared aspect among various rating systems, albeit with some variances. It is imperative that there is an enhancement of intermodal public transportation and an integration of alternative mobility systems into urban planning in order to achieve better organization in urban centers, as well as to reduce land use and tackle climate change (Francini et al., 2019). Furthermore, as planners, it is essential to evaluate the quality and not solely the amount of services given to citizens and stakeholders. Subsequently, it is vital to observe the effects of the project over a period of time to adjust tactics in response to the altered perception regarding the quality of life (Bosch et al., 2017). The monitoring activity implemented with GBC Neighbourhoods protocol necessitates skillfully weighing the introduced objectives to attain high-quality urban spaces. This involves providing an accurate depiction of prevailing conditions and then utilizing appropriate methodologies to accomplish the city's urban and environmental quality goals.

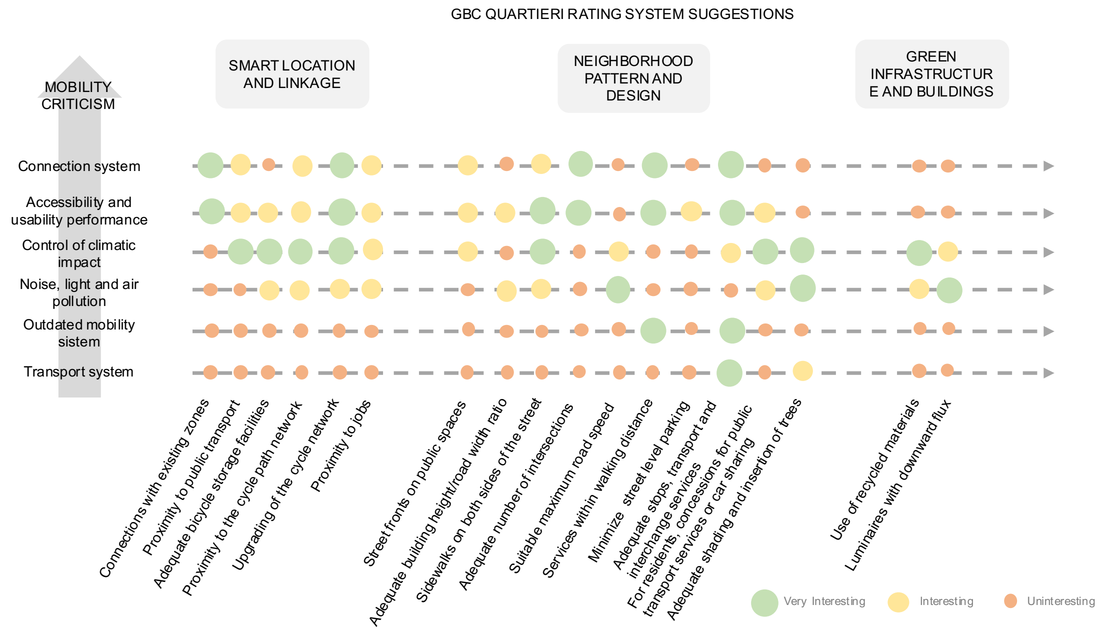

Fig.2 Linking the suggestions given by GBC Quartieri rating system to the mobility criticism described in the introduction

By thoroughly analysing the requests outlined in the GBC Quartieri protocol, recommendations for a sustainable transport and mobility design can be identified. These suggestions can then be linked to the crucial aspects highlighted in the introduction and addressed in the literature. In Fig.2, the evaluation of parameters is displayed, with suggestions grouped by their main category and further categorized based on their relevance to mobility criticism. In this way, it is possible to see how certain design suggestions are more or less related to mobility-related criticalities; alternatively, if read in the opposite direction, the possible solutions specified in the protocol can be found through the interest or lack of interest highlighted. Then, one can determine the extent of the relationship between particular design recommendations and matters related to mobility, or alternatively, recognise potential resolutions detailed in the protocol depending on the degree of interest expressed. This analysis is limited by the subjectivity of the planner conducting the study. Only after numerous analyses can the findings become generalizable and repeatable, or they should be derived from a participatory approach (Delsante, 2016). The analysis is limited by the subjectivity of the planner conducting the study. This approach aims to meet the criteria of objectivity (clarity, ease of comprehension, precision, and unambiguity), relevance, reproducibility (systematic observance), and validity (with), the possibility of verification, representativeness at the city level, comparability over time, and accessibility through the use of existing databases and data. The range proposed varies in interest (from very interesting to uninteresting), depending on the degree of correlation and interconnection between the criticism of mobility and the solution offered in the protocol.

To assess the project outlined below, quantitative verification is necessary in addition to qualitative and descriptive analyses. Relying solely on attainable credit values is inadequate as it could result in an assessment that does not align with our goals. The aim is to evaluate the success or failure of the projects in meeting mobility requirements by offering solutions to commonly identified key issues highlighted in the introduction through the protocol currently under review. To achieve this, weights to the reports exhibited in Fig.2 were allocated, which are then multiplied by the number of credits suggested in the protocol or by 1 in the case of a prerequisite, illustrated in (1).

$$SW_n = \sum (p_{cn} \times C_n) \tag{1}$$

Where:

- SW_n is the weight of the solution under analysis (for example, transport system or accessibility and usability performance);
- p_{cn} is the weight of the criticism assessed in Fig.2. If the link is deemed highly interesting, it is given a value of 5; if interesting, a value of 3; and if uninteresting, a value of 1;
- C_n is equal to the maximum number of credits suggested by the protocol or 1 in case of a prerequisite.

The resulting table shows GBC Quartieri's primary focus on connection system (149 weight points), accessibility and usability performance (191 weight points), climate impact control, and noise, light and air pollution (215 weight points). Conversely, less importance is placed on outdated mobility (63 weight points) and transport system concerns (63 weight points).

The limitations of the method are attributable to the approximations employed, ranging from the subjective selection of credits and prerequisites related to mobility, to the weighting of the interconnections between criticalities and solutions provided by the protocol. To explore this further, minor weights of 1, 2 and 3 were tested for p_{cn} within formula 1, leading to a highly comparable conclusion.

4. Results

To assess the outlined methodological system, it is applied to the Le Albere project case study. This is a project situated in Trento that was commissioned to RPBW-Renzo Piano Building Workshop in 2013. Its objective was to transform an abandoned and heavily polluted industrial site into a green landscape. This new, highly technical district rejuvenates an eleven-hectare area that was once the site of the Michelin factories until 1998. This transformation was made possible due to the proximity of the two main infrastructures, the railway, and the Adige River.

The project aims to achieve sustainability, compatibility with the environment, and energy conservation. Its objectives include the revitalization of the river belt and restoring the connection with the city that was previously hindered by the railway barrier. Its objectives include the revitalization of the river belt and restoring the connection with the city that was previously hindered by the railway barrier. This impediment has been eradicated with a system of pedestrian and vehicular underpasses, enabling residents to traverse old and new neighbourhoods seamlessly. The presence of ponds, ditches, and small canals emphasises the need to connect the city with the river. The main idea was to merge the buildings to the east, close to the railway line, in contrast to the vast park on the western side, which borders on the Adige River, separated by a long tree-lined avenue that stretches up to 300 metres.

The functional mixity characterises both the composition of the individual buildings, encompassing various typologies ranging from residential to office spaces, shops, and cultural venues, as well as the entire district, which includes the Science Museum, a multipurpose centre, and a hotel.

GBC Quartieri				Mobility Criticism weight SW_n					
Smart Location & Linkage				Connection system	Accessibility, usability performance	Control of climatic impact	Noise, light, air pollution	Outdated mobility system	Transport system
Code	**Description**	**min**	**max**						
LCS_p1	Smart Location	X		5	5	1	1	1	1
LCS_c1	Preferred Locations	1	10	30	30	50	10	10	10
LCS_c3	Access to Quality Transit	1	7	7	21	35	21	7	7
LCS_c4	Bicycle Facilities	1	2	6	6	10	6	2	2
LCS_c5	Housing and Jobs Proximity	1	3	15	15	15	9	3	3
Neighborhood Pattern & Design									
Code	**Description**	**min**	**max**						
OPQ_p1	Walkable Streets	X		3	3	3	3	1	1
OPQ_p2	Compact Development	X		3	3	3	1	1	1
OPQ_p3	Connected and Open Community	X		1	3	1	3	1	1
OPQ_c1	Walkable Streets	1	9	27	45	45	27	9	9
OPQ_c2	Compact Development	1	6	30	30	6	6	6	6
OPQ_c3	Mixed-Use Neighborhoods	1	4	4	4	12	20	4	4
OPQ_c5	Reduced Parking Footprint	1	1	5	5	1	1	5	1
OPQ_c6	Connected and Open Community	1	2	2	6	2	2	2	2
OPQ_c7	Transit Facilities	1	1	5	5	3	1	5	5
OPQ_c8	Transportation Demand Management	1	2	2	6	10	6	2	2
OPQ_c14	Tree-Lined and Shaded Streetscapes	1	2	2	2	10	10	2	6
Green Infrastructure & Buildings									
Code	**Description**	**min**	**max**						
IES_c15	Recycled and Reused Infrastructure	1	1	1	1	5	3	1	1
IES_c17	Light Pollution Reduction	1	1	1	1	3	5	1	1
				149	**191**	**215**	**135**	**63**	**63**

Tab.3 Table illustrating the distribution of solutions weight of mobility criticism in GBC Quartieri protocol, through the use of formula 1. Colours are the same used in Figure 2

The buildings situated in a line are intended for office and management functions, while the courtyard blocks are reserved for 300 residential flats. With the exception of the museum and multifunctional center, all of the buildings are no more than 18 meters in height, matching the size of the previous industrial establishments. The roofs boast sharp blades, sloping like the Dolomites, and are equipped with sizable solar-powered systems. At an infrastructure level, the project includes underpasses and connections, as well as avenues that mirror the proportions of the streets of the Renaissance palaces found in the city centre. Vehicular traffic is limited to the main north-south artery, and most parking lots are underground, allowing for more green spaces and pedestrian areas (Ciccarelli, 2014) (Malvasi, 2013). The criticism of this project centres around:

- The promised creation of a "river park" open to citizens did not materialize;

- High rents for residential properties have resulted in low occupancy rates, with around 50% of them remaining unoccupied (Sanò et al., 2021);
- The residential area has become a temporary shelter for marginalised individuals who seek accommodation for the night. Although the neighbourhood is bustling with young professionals, tourists, students and families during the day, it is quiet and almost deserted at night (Sanò et al., 2021).

In regards to rating systems, the MUSE museum building has received certification. Specifically, it has obtained the gold-level LEED New Construction v 2.2 certification, with the following performances: 10/14 for sustainable site, 5/5 for water management, 6/17 for energy and atmosphere, 6/13 for materials and resources, 10/15 for internal environmental quality, and 5/5 for innovation design (Green Building Council Italia, 2016). The system achieved certification through the implementation of geothermal probes, solar cells, and rainwater harvesting.

GBC Quartieri			Mobility Criticism weight SW_n					
Smart Location & Linkage			Connection system	Accessibility, usability performance	Control of climatic impact	Noise, light, air pollution	Outdated mobility system	Transport system
Code	Description	Le Albere Points						
LCS_p1	Smart Location	X	5	5	1	1	1	1
LCS_c1	Preferred Locations	8	24	24	40	8	8	8
LCS_c3	Access to Quality Transit	5	5	15	25	15	5	5
LCS_c4	Bicycle Facilities	2	6	6	10	6	2	2
LCS_c5	Housing and Jobs Proximity	2	10	10	10	6	2	2
Neighborhood Pattern & Design								
Code	Description	Le Albere Points						
OPQ_p1	Walkable Streets	X	3	3	3	3	1	1
OPQ_p2	Compact Development	X	3	3	3	1	1	1
OPQ_p3	Connected and Open Community	X	1	3	1	3	1	1
OPQ_c1	Walkable Streets	9	27	45	45	27	9	9
OPQ_c2	Compact Development	3	15	15	3	3	3	3
OPQ_c3	Mixed-Use Neighborhoods	4	4	4	12	20	4	4
OPQ_c5	Reduced Parking Footprint	1	5	5	1	1	5	1
OPQ_c6	Connected and Open Community	1	1	3	1	1	1	1
OPQ_c7	Transit Facilities	1	5	5	3	1	5	5
OPQ_c8	Transportation Demand Management	1	1	3	5	3	1	1
OPQ_c14	Tree-Lined and Shaded Streetscapes	1	1	1	5	5	1	3
Green Infrastructure & Buildings								
Code	Description	Le Albere Points						
IES_c15	Recycled and Reused Infrastructure	0	0	0	0	0	0	0
IES_c17	Light Pollution Reduction	1	1	1	3	5	1	1
			117	**151**	**171**	**109**	**51**	**49**

Tab.4 Table illustrating the distribution of solutions weight of mobility criticism in Le Albere project, through the use of formula 1. Colours are the same used in Fig.2

Upon examination of the previous paragraph on Le Albere, it is feasible to assess potential enhancements that can be implemented in the neighbourhood. Specifically, although the plan was designed before the introduction of neighbourhood-scale rating systems, it possesses ample public spaces, is well-linked, enjoys good public transport access and adequate lighting. It should be noted that, to enhance the facility, the protocol proposes supplementing additional bicycle storage units that are secure and safe, utilizing sustainable materials for any future constructions, and enhancing connectivity with the current zones.

Turning to the quantitative evaluation proposed above, it can also be seen that the project obtained, through the use of formula 1 and replacing the maximum C_n credits with those actually obtainable from the project, according

to information gathered from reference publications, a shortlist of solutions that come close to the protocol under consideration, without shifting too much to some solutions to the detriment of others (Tab.4).
Further analysis of the obtained data reveals that the project fulfills almost 80% of the mobility requirements specified in the protocol. Better performance is achieved for obsolete mobility systems and for mitigating noise, light and air pollution. However, it is less effective for the transportation and connection systems (Fig.3).

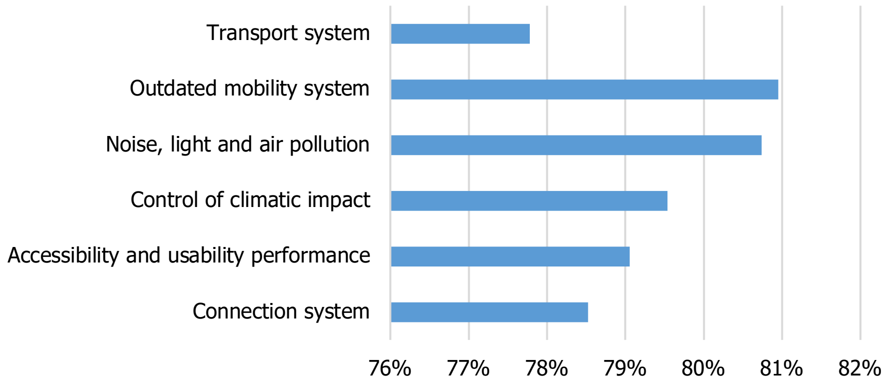

Fig.3 Graph showing the percentage of mobility criticisms addressed by the Le Albere project solutions

3. Conclusions

In the context of sustainable development and environmental concerns regarding urban growth, local transformation and redevelopment initiatives should aim to minimize negative impacts by evaluating the environmental, social and economic aspects. Consequently, it is crucial to reconsider transport planning and establish policies that assess the system of connections, organization, accessibility, environmental pollution, noise pollution and light pollution. Urban-scale sustainability protocols can aid planners and lawmakers in assessing and contrasting distinct projects. This study assesses the effectiveness of the GBC Quartieri protocol in transport-oriented contexts. The protocol, currently implemented in only one case in Italy, is analysed using a method that evaluates the internal characteristics of each solution provided for the critical issues found in mobility literature. The protocol's recommendations account for more than half of the overall achievable score and successfully address existing concerns regarding improvements in this sector.
Then, in order to be able to quantitatively analyse an actual project, the answers to the critical questions collected on mobility were weighted within the protocol. In this way, the Le Albere case study in Trento could also be analysed and checked in terms of the objectives achieved, with the overall result being a very good one that could be improved through a better implementation of the transport system and connections with the existing city.
In general, noteworthy outcomes were observed:

- It is necessary to monitor implemented projects and update them to respond to new environmental, social, and market challenges. Indeed, although the Le Albere project exhibits high-level characteristics, it requires further improvement to address the contextual needs articulated in the criticism of its description, which was only identified post-implementation;
- Urban planning is often evaluated as a secondary consideration to single building construction, yet for large complexes, it should be the primary theme to address as it can create marketing appeal and attractiveness;
- To enhance transportation and mobility and assess the attainment of 50% credit, it is crucial for the public sector to consider the implementation of these evaluation systems at the design and maintenance level in the long term.

For future implementations, the proposed method visible in Fig.4 could be used to compare this project with other neighbourhood redevelopment projects or to assess the internal attributes of other urban-scale protocols like BREEAM Communities or CASBEE Urban Development.

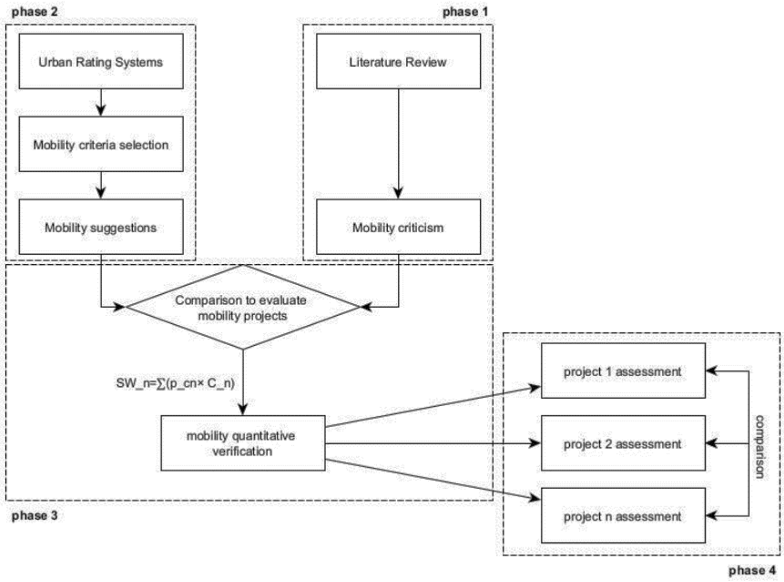

Fig.4 Generic flowchart of the proposed methodology for future implementations

The suggested approach may be modified by tweaking the allocated weights or overhauled completely to tackle any additional issues by commencing from scratch to compile a list of credits and prerequisites pertaining to the topic, scrutinising the provision of solutions, allocating weights and scrutinising current or ongoing projects.

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Image sources

Figg.1 - 4: Authors' elaboration

Author's profile

Elena Mazzola

She is currently a researcher and an Assistant Professor in the faculty of Engineering in Padua (Italy). She obtained her PhD in Architecture, City and Design from Iuav of Venice University, published a number of papers in preferred journals, and presented various academic as well as research-based papers at national and international conferences. Her research activities are currently twofold: while the first research activity is set to explore the efficiency of buildings, the second major research theme is focused on the develop of sustainable urban cities.

Alessandro Bove

He is a researcher in urban planning and technics at the department ICEA of Padua University. He is building engineer with expertise in urban and spatial planning and special interest in resilience and sustainability planning. He had his PhD in Building and Territorial Engineering (Bologna University, 2009). His research experiences are characterized by a practical approach because He always tried to combine theoretical research with design. The main themes of interest regard the sustainable urban transformation/regeneration, with a specific attention to industrial areas, the reuse of abandoned infrastructure and the protection of landscapes. On these themes, He had the opportunity to participate to national researches, to international cooperation projects and to public and private initiatives with research interest as regional and urban plans, strategic projects, often as leader or as coordinator. He is actually the President of Padua Engineers Foundation, private body active in the innovation and continuous education for engineers.