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Transportation Research Procedia 60 (2022) 306–313

Transportation Research Procedia

www.elsevier.com/locate/procedia

XXV International Conference Living and Walking in Cities - New scenarios for safe mobility in urban areas (LWC 2021), 9-10 September 2021, Brescia, Italy

New Milan metro-line M4. From infrastructural project to design scenario enabling urban resilience

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Abstract

Resilience is an attitude of a system to cope with shock or stress and to guarantee its continuity. Referring to a city or a neighborhood, a resilient system is an urban body that can sustainably adapt to natural and climate hazards, economic, social, and technological shocks. Moreover, it can sustainably transform solving chronic problems such as traffic, air, and noise pollution.
The city of Milan is the case study where trial the re-designing of sustainable, safe, and resilient urban space. The Green-blue backbone project re-shapes a chain of public spaces according to the development of the new metro line M4. The Green-blue backbone is a network of paths and public spaces for pedestrians and cyclists that cross the city center and connect two parks. Its design and implementation are tuned with historic heritage and peripheral neighborhoods and facing their resources through active mobility development. The paper discusses the Masterplan proposal aimed to convert a simple infrastructural project into a well-organized urban space design. Urban design priorities were a high visual appeal, easy and simple maintenance, high ecological function, cultural heritage protection, and sustainable mobility. The Green-blue backbone project pushes Public Administration to re-consider urban space design to implement new local connections and new metropolitan identities according to a sustainable transport system, and to re-think the common background where the community might be resilient. In particular focusing on ecological, functional, and perceptual aspects that are effective elements in creating urban resilience. From an urban planning perspective, Milan's Green-blue backbone is the opportunity to realize safer and resilient public spaces and sustainable mobility, looking at the time-space design of the public transport and ecological network.

Keywords: active mobility; adaptive urbanism; public space; urban design; urban health.

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10.1016/j.trpro.2021.12.040

1. Introduction and state of the art

The paper's research question is Can we use the design of new metro line to increase urban resilience? Urban resilience is widely investigated in contemporary research, e.g., assessing the urban morphology and street network performance (Marcus & Colding, 2014; Sharifi & Yamagata, 2014; Frantzeskaki, 2016; Sharifi, 2019). Despite this, the research gap is operative, and it concerning how to gain resilience in the densely built-up city.

Generally, the concept of resilience is analyzed regarding shocks such as earthquakes or terrorist attacks (Gomes Ribeiro & Pena Jardim Gonçalves, 2019). Instead, here urban resilience is understood as the ability of a system to transform itself after stress (Desouza & Flanery, 2013). The paper assumes the continuous disturbance caused by traffic and the poor quality/continuity of public spaces as threat to cities' liveability. Considering the stress factors, mobility and urban design become the vulnerability parameters to increase urban resilience. The paper presents research result that combines walking, cycling, and urban design within sustainable and resilient planning perspective in line with Transit-Oriented Development approach (Dittmar & Ohland, 2004; Carlton, 2009).

Since the 90s, the role of the transports sector has augmented (UN, 1992). It represents a key field for sustainable development because it is the primary driving force behind a growing world demand for energy. At the same time, the transport sector is crucial for people's security and health. Negative externalities of road transport are air pollution, noise pollution, road crashes and deterrent effects on walking and cycling, and the reduction of life quality beyond social isolation (WHO, 2010). Indeed, in the 2030 United Nations Agenda for Sustainable Development, sustainable transport is mainstreamed across several Sustainable Development Goals, especially those related to food security, health, energy, economic growth, infrastructure, and cities and human settlements (UN, 2015).

The World Health Organization's report on road safety highlighted the severe danger of road transport, which causes many accidents every year, mainly affecting young people 5-29 years old, and in Europe involving many cyclists (WHO, 2018). In Milan, between 2001 and 2019, the average number of pedestrians killed by car crashes is 21 per year. The awareness about the problems launched the European 'Zero Victims' program, which aims by 2050 both to bring about a cultural change (road deaths can no longer be tolerated) and enable the development of synergies between safety and sustainability measures. For example, less car use in cities combined with safer environments for pedestrians and cyclists will reduce gas emissions, improve air quality, ease congestion and contribute to a more active and healthier population (EC, 2019).

Another externality of road transport is pollution. Air pollution and noise pollution are a growing environmental concern. Transport-related air and noise pollution, produced mainly by diesel vehicles, causes a wide range of health problems. Similarly, noise pollution threatens people's health and well-being. While environmental pollutants from the transport sector have decreased, exposure to noise levels remained constant in urban areas (EEA, 2016). According to 'Europe on the Move' European policy, the goal is tomorrow's mobility system will be safe, clean, and efficient for all citizens (EC, 2018).

The European target is in line with the definition of the '15-minute city' (Moreno, 2016), which requires urban development on a human scale, i.e., a settlement system in which everyone can find the services they need at a maximum distance of 15 minutes by foot or by bicycle (Duany & Steuteville, 2021).

In European cities, 50% of car trips have a distance of less than 5 km (Dekoster & Schollaert, 1999). Active modes of transport can easily do this distance. Moreover, city users see minimising time and cost as 'desirable', and therefore their reduction is directly related to the potential of transferring trips to other transport modes (Monzon, Vega & Lopez-Lambas, 2011). The concept of 'sustainable city' includes the idea of 'active mobility'. Active mobility is a set of motion types around the city, such as walking, cycling, and using public transport. Active mobility has multiple implications for health by changing the exposure to specific health determinants like physical activity, traffic incidents, air pollution, noise, social interaction, and crime.

The new Milan metro line (M4) construction sites were the starting point to increase urban resilience by re-designing cycling-walking areas and public spaces (Abastante et al., 2020), stimulating active mobility, and reducing traffic. In the research, the new metro stations are nodes of a 'territorial network' that combine flows, identities, infrastructural spaces, and ecological corridors (Pucci, 1996).

The paper shows the process and results of a multi-scalar project (di Venosa, 2014), from the urban dimension to the neighbourhood dimension to the architectural size, combining resilience, urban design, local identity, and active mobility topics. It is a '*progetto di suolo*' (project of the ground/space design) (Secchi, 1986, 2006) that reconfigures

routes and open spaces consistently with the development of the new metro line and the places' singularity. The project widens the range of city movement occasions by stimulating active mobility. Moreover, the project highlights adaptive capability instead of territorial vulnerabilities. According to Vich, Marquet, and Miralles-Guasch (2019), it is the consistency and density of green elements and the design of public space that intensify the pedestrian and bicycle use of cities. Consequently, increasing the network and continuity of these spaces leads to an improvement in health and safety of citizens because it encourages their freedom of movement and, at the same time, reduces the negative externalities of road traffic. Simultaneously, detailed and precise design is needed to choose materials, space design and urban furniture, and the inclusion of green spaces and ecological amenities that enhance people's comfort, perception of well-being, and health. These aspects determine a resilient urban design (Lak, Hasankhan & Garakani, 2020), contributing to climate change adaptation (Tamminga, Cortesão & Bakx, 2020) and improving the sociality of the streetscape. Indeed, these design aspects can encourage users to stay on streets, by foot or by bicycle, consolidating 'a life between buildings' (Gehl, 2011) and self-sustaining resilience.

Other researches outlined only a set of urban regeneration policies according to the principles of sustainable mobility and urban liveability (Ndukwe, 2018). Instead, the Milanese experience concerns the direct applicability of the design outputs in urban planning tools, such as land-use plan, sustainable urban mobility plan, pedestrian and cycle plan, public transport plan. The project stresses the multi-scalar design actions that can be applied at various levels of urban transformation: from the urban plan to the architectural project.

The design of the Green-blue backbone is an urban project that deals with contemporary phenomena. Some papers highlighted essential issues addressed by the research. Namely, those papers offer a compelling demonstration of how to apply green infrastructure in built-up cities (Fior, Vitillo & Galuzzi, 2019) and re-value the historical heritage (Fior, 2020). Instead, this paper focuses on improving public transport usability by pedestrian and cycle routes, increasing people's health and safety during daily trips. The paper contributes to mainstream the literature with a case study in resilient urban design increasing urban resilience through sustainable and integrated mobility.

The paper consists of three parts. The first part (ph. 2) shows materials and the working method used in the research. The second part (ph. 3) shows the research outcomes that are the Masterplan of the Green-blue backbone and the design of space around Forlanini FS metro station. The third paragraph is crucial because it sums-up the planning guidelines proposed at different scales to achieve active mobility and urban resilience. The third part (phs. 4) reports the main results and relates them to other research in the same field. The goal is to show the innovative role of the study, as research in action, and the opportunity to develop others in line with it.

2. Materials and methodology

The design proposal of the Milan's Green-blue backbone arose with a traditional working method based on analysis, master planning, and urban design.

The development of urban, environmental, and transport-oriented analyses in GIS environment helped to discover opportunities and threats at urban scale. Municipality of Milan and M4 SpA provided own data and other open source data were retrieved from regional (*Geoportale Lombardia*) and national database (*Istat*).

The urban, landscape, environmental, and transport system analyses covered three thematic fields:

- the assessment of the M4 stations' accessibility by foot (using pedestrian isochrones);
- the mapping of urban functions that generate or attract city users (attractors and traffic generators);
- the mapping of services and urban transformation opportunities present in the M4 stations surrounding.

The pedestrian accessibility was calculated considering pedestrian isochrones of 5, 10, and 15 minutes (high, medium, low pedestrian accessibility) using the Open Route Service plugging in QGIS (Fig. 1a). The catchment areas highlighted the walkability network considering the urban constraints such as architectural barriers and discontinued connections. The Sustainable Urban Mobility Plan offered other information (2018), such as Limited Traffic Zones or existing/predicted cycle lanes. The collected information suggested where to increase the pedestrian area through new safe routes or improving the continuity of existing itineraries. The Green-blue backbone Masterplan is a network of slow-mobility that considers the level and the quality of the pedestrian accessibility around the M4 stations.

The distribution of uses and functions that generate and attract users was necessary for understanding stations' functioning and design. Using census data (2011) about inhabitants and enterprises, geospatial operations designed maps of 'attractors' and 'generators' (Fig. 1b). Attractors are companies, tertiary-commercial, and service activities, while generators are residential districts. The number of enterprises per census area and the number of employees per census area were used to analyze the attractor districts. On the other hand, the number of inhabitants per census area was used to analyze the generator districts. The maps allowed the evaluation of the flows potentially generated and attracted in each station. Moreover, they were helpful to assess whether there are conditions for possible densification (building rights transfer) around the transport node.

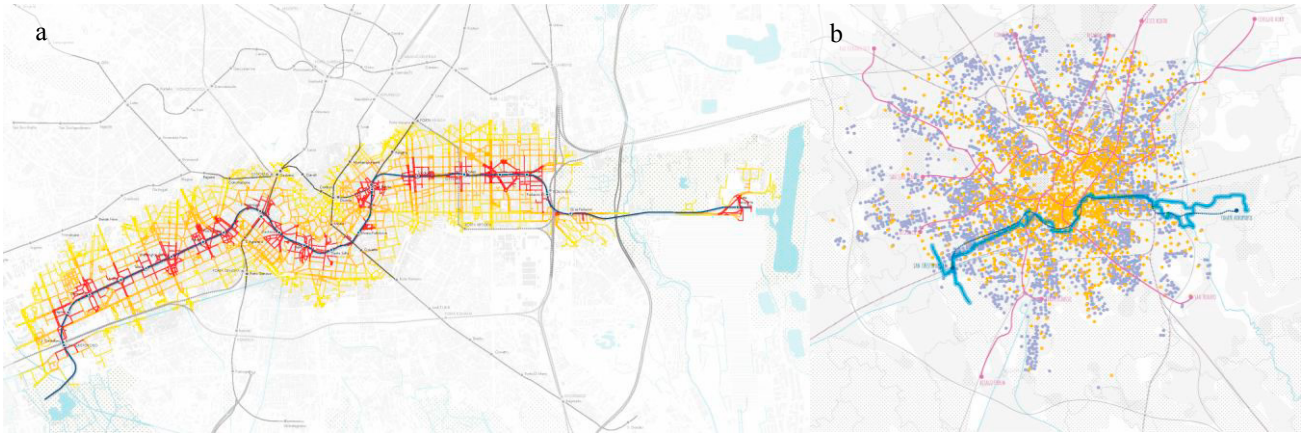

Fig. 1. (a) Pedestrian isochrones along M4 line; (b) Attractors (orange dots) and Generators (purple dots).

Data on land use and land cover by the Municipality of Milan was used to map services, public facilities, and urban transformation all around the stations. The mapping involved the existing and planned system of public facilities (green and sports areas, education, universities and research districts, health services, and social housing, etc.), as well as strategic functions (conference centers, theatres, museums, libraries, shopping mall, etc.), transformation areas predicted by the Urban Plan (*Piano di Governo del Territorio* - Territorial Government Plan), and existing disused or underused areas. The aim was to improve the knowledge of the urban context within the pedestrian isochrones, identifying the strengths and weaknesses of each station. Moreover, the goal was to identify thematic issues for the urban project.

The Masterplan design and the definition of the project guidelines for the entire Green-blue backbone offered technical support to coordinate future urban development (Fig. 2). At the city scale, the output is a map discussed and designed through a co-design process with Municipal offices.

Finally, the implementation of hot-spot areas, particularly relevant for urban re-greening, slow-mobility connection, public facilities, and cultural identity, helped test the guidelines and suggested public spaces regeneration. The hot-spot design implementation was an essential phase of the design process because urban actors (politicians, technicians, and experts) were involved to co-create innovative and resilient urban neighborhoods.

3. Master planning and urban design results

Briefly, the action-research developed four specific activities. The main outcomes are maps.

1. The Urban Contexts Analysis (*M4 incontra la città* - M4 meets the city) output a list of maps, at city scale, covering different topics (from environment to mobility). The most important topic is the assessment of walkability around the new metro stations.
2. The Masterplan Design (*M4 incontra i territori* - M4 meets neighborhoods) output a Masterplan, at urban scale, that cover the entire M4 line and the design of pedestrian and cycle network.
3. The new Urban Hubs Development (*M4 incontra lo spazio urbano* - M4 meets urban space) output 21 Masterplans, at local scale, one for each new metro station.

4. The Design Guidelines (*M4 incontra i luoghi* - M4 meets places) output a set of planning recommendations for some metro stations. This activity was dedicated to the space design of the open air space around the metro station.

Downstream of the knowledge acquired in the analysis phase, the research considers the new M4 line as the opportunity for developing a linear green and blue park. The metro line, running underground, develops a system of interconnected spaces defined as green-blue backbone on the surface. The design links several environmental systems – the regional park (*Parco Agricolo Sud*), the metropolitan park (*Grande Parco Forlanini*), the Lambro River and the seaplane base (*Idroscalo*) – reduces the traffic impact, and promotes active mobility. This system of routes, green areas, water connections, urban services, public transport nodes is the Green-blue backbone of Milan 2030. The backbone has a metropolitan dimension that touches the city center and reaches the municipalities of the first belt (Segrate, Peschiera Borromeo, Buccinasco, Corsico).

The new metro line crosses Milano city from East to West, touching working-class neighborhoods and the historic center. All the new stations are in dense urban areas, and assessing their accessibility meant questioning the level and the quality of pedestrian (and cycle) usability. Moreover, the distribution analysis of generators and attractors was helpful indicator for estimating the station's pedestrian flow and understanding their temporal distribution over the day. Generators require a transport demand mainly concentrated in the morning peak hours (as entrance flows) and in the evening (as exit flows). While, according to their economic activity, attractors' demand is complementary to the generators in terms of entrance/exit flows. Generators and attractors map was essential for orienting public space design around stations through the safety and requalification of the pedestrian access routes.

In the Green-blue backbone, M4 stations are proper 'urban thresholds' – thus complex urban environments that include homes, services, and activities – that provide access to the infrastructure. Stations are not just the points of the metro route that collect, distribute and bring flows of people to the surface. Station nodes are hallmarks of the city's present time. Stations are 'enabling platforms' for environmental (water, parks, and green areas) and infrastructural systems (trains, metro, buses, cycle paths, squares). Stations are places of memory, including the city's past, i.e. the history of the city; the city's present, i.e. the culture produced (living memory); and the city's future because stations are places of urban transformation. For those reasons, the research developed 21 local Masterplans, one for each station. These Masterplans have given great importance to the recognizability of the stations and their neighborhoods. The stations' recognizability is closely linked to the territorial context in which they are located. The urban analyses defined the design issues for each station. By way of example, Segneri and Frattini stations are described as 'connectivity hubs'. For them, the Masterplan offered solutions to overcome the discontinuity of the routes, creating new connections and enhancing existing urban relationships. The aim was to extend the pedestrian isochrones and bring the stations closer to the neighboring areas, stimulating a behavioral change and promoting active mobility.

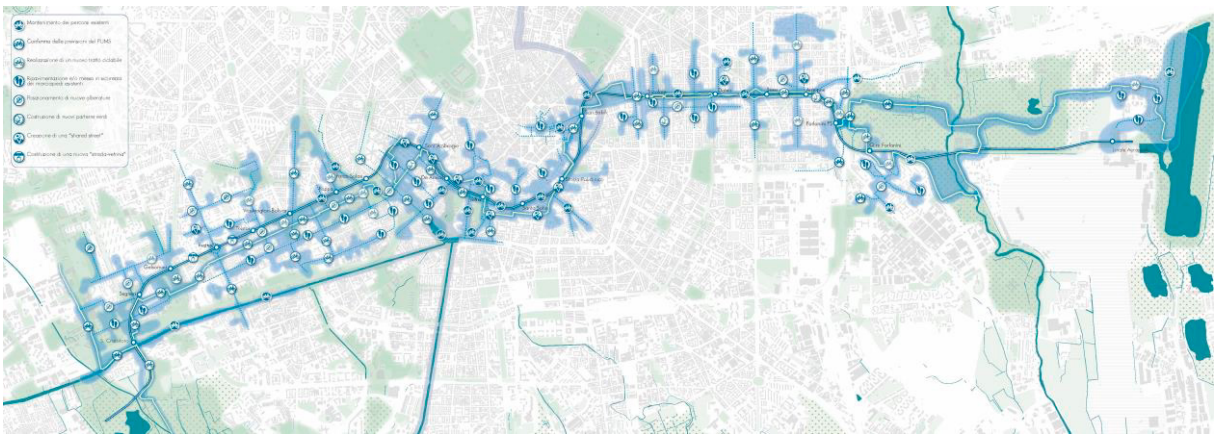

Fig. 2. The Masterplan Design. The Green-blue backbone.

The last part of the research produced design guidelines for three stations and their urban areas (Frattini, Sforza-Policlinico, Forlanini FS). The case studies are particularly relevant in urban renewal, connection to slow-mobility, public facilities, and cultural identity.

The paper shows the results for Forlanini FS station (Fig. 3). The station is in the eastern part of the M4 line, combined with the suburban railway station. The surrounding is characterized by the XIX Century settlement fabric, the proximity to metropolitan park (*Grande Forlanini*), and a large green area called '*Pratone*' (giant meadow). The *Pratone* is an open space of 15,000 square meters, partly planted with trees, which until 2013 was available to the inhabitants for games, walks, and recreational activities. In particular, the *Pratone* area is adjacent to the new M4 station. It was one of the most exciting areas for in-depth design, increasing the resilience of the surrounding urban fabric and expanding the ecological and environmental corridors.

The design recommendations goal was to arrange the area considering the needs of the inhabitants, mainly foreign people and families. In particular, the proposal provides the restoration of the green area increasing the continuity of bicycle and pedestrian paths between the metro stop, the city, and the metropolitan park. The proposed design guaranteed the green open space integrated with new public facilities (playgrounds, bar, and kiosk) and dedicated to outdoor movement with areas equipped for free-body sport (Fig. 4).

In the project, the *Pratone* returns to being a neighborhood space, protected and domestic, such as an access point to the system of open spaces at metropolitan scale. The project anticipates and creates a system of multifunctional, complex, and connected areas. The system allows people to move by foot safely, through tree-lined spaces and lawns, from the center of Milan to the *Idroscalo*. The network of slow-mobility allows to quickly accessing places and public facilities that would otherwise be distant and separate from the neighborhood (such as the Junior Tennis Club, the historic Scarioni football club, the Sant'Ambrogio farmstead).

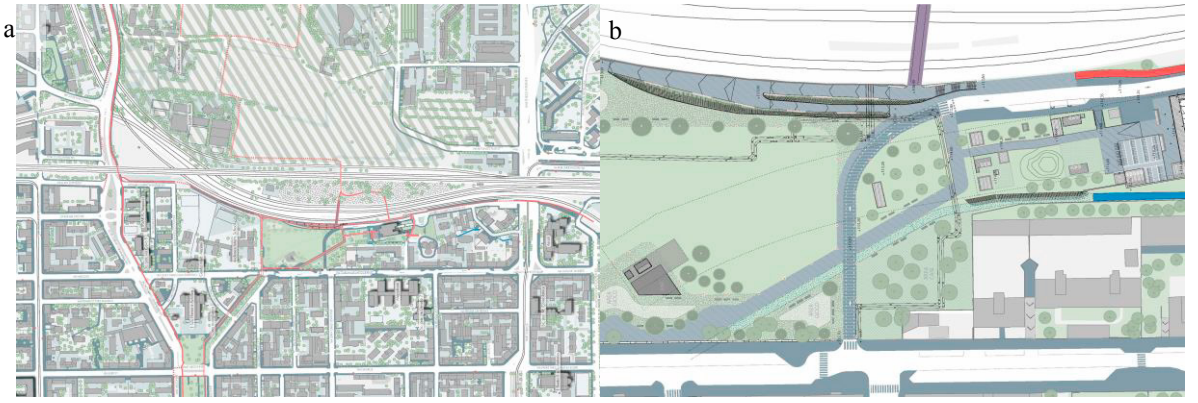

Fig. 3. The Design Guidelines. Forlanini FS station and 'Pratone' area. (a) Urban connections; (b) Architectural design.

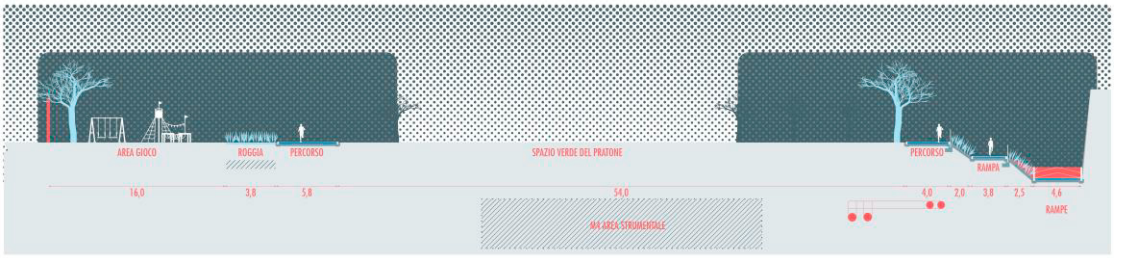

Fig. 4. 'Pratone' area. Open air spaces and paths for outdoor activities.

4. Discussion and usefulness of research

Pedestrian areas, bicycle lanes, and efficient public transport are key to promoting sustainable, safe and active mobility routes, thus a resilient city. A network of paths and areas oriented to:

- the improvement of urban life quality. Promoting safe and healthy spaces for workers, inhabitants, students, shoppers, and tourists.
- the extension/articulation of ecological corridors inside the compact city. Promoting de-sealing and re-greening solutions for paved public areas.
- the re-balance metropolitan equilibrium improving the accessibility/liveability of different neighbourhoods. Promoting the design of attractive and human places and increasing sustainable connections among districts.

Cities such as Strasbourg (Strasbourg Eurometropole) or Wien (Stark, Frühwirth & Aschauer, 2018) combine cycling and walking with urban resilience. They have experienced 20 years urban policies on sustainable urban development. In other cases, projects and research on active mobility have focused on target groups, such as mothers, children/adolescents, and the elderly, to encourage independence in travel or reducing diseases such as obesity, hypertension, and other heart illnesses (Montoya-Robledo et al., 2020; Papa, Carpentieri & Guida, 2018).

In contrast to these experiences, the Green-blue backbone project indicates ways to increase urban resilience through multi-scalar urban planning. On the one hand, big transformative projects (such as new metro line) is an engine for sustainable development. They might be an opportunity to integrate, at different scales, the improvement of green and blue corridors, cycling and walking routes and the renewal of public spaces. On the other hand, the project's target audience was widened as much as possible: not only specific categories of the population (younger, the elderly, the chronically ill, women) but citizens, commuters (workers and students), and tourists, who lives and populate the city daily.

5. Conclusions

To increase urban resilience from chronic stress such as traffic, long-term coordination, and planning of urban-scale projects are necessary through simple planning tools based on constructing a framework. Organizing routes and spaces for resting and contemplating the urban landscape with green and blue corridors, open-air spaces, playgrounds are essential too. Moreover, organizing interchanges between public transport and sustainable mobility are crucial to reducing road traffic and increasing active mobility.

In Milan, the project of the Green-blue backbone result is twofold. First, it provides a directly applicable and feasible tool (the Masterplan) on current urban planning and mobility programs pushing the Municipality to coordinate them, manage transformation during the time, and improve urban resilience. The Masterplan is an agile, multiscale and widespread design tool in many countries. It could be applied in many other cities integrating different scales of analysis and projects facing with various topics (environment, mobility, cultural heritage, etc.). Second, the resilient urban design developed and crossed public transport, cycling-walking routes, green corridors, and public spaces, proposing various mobility supplies. The Milanese experience leads the project towards a broad public to trigger a behavioural change in moving into the city (home/work and leisure trips), reducing traffic, air, and noise pollution. Moreover, the project stresses the power of public space as a link between functional areas. The redesign of public space could transform ordinary attitude on moving, emphasizing the benefit of a walk and cycle to appreciate the cultural heritage, take advantage of open-air spaces, and reduce pollution and cars crashes.

The principal limit of the research project is the absence of a participatory process. While the Municipality of Milan developed some co-design workshops to transform few metro stations, the Green-blue backbone project was not discussed with inhabitants even if the Municipality guaranteed maximum dissemination of its results.

Acknowledgements

Authors thank Department colleagues and collaborators involved in the project, the Municipality of Milan, MM SpA, SPV M4 SpA, and AMAT Srl.

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