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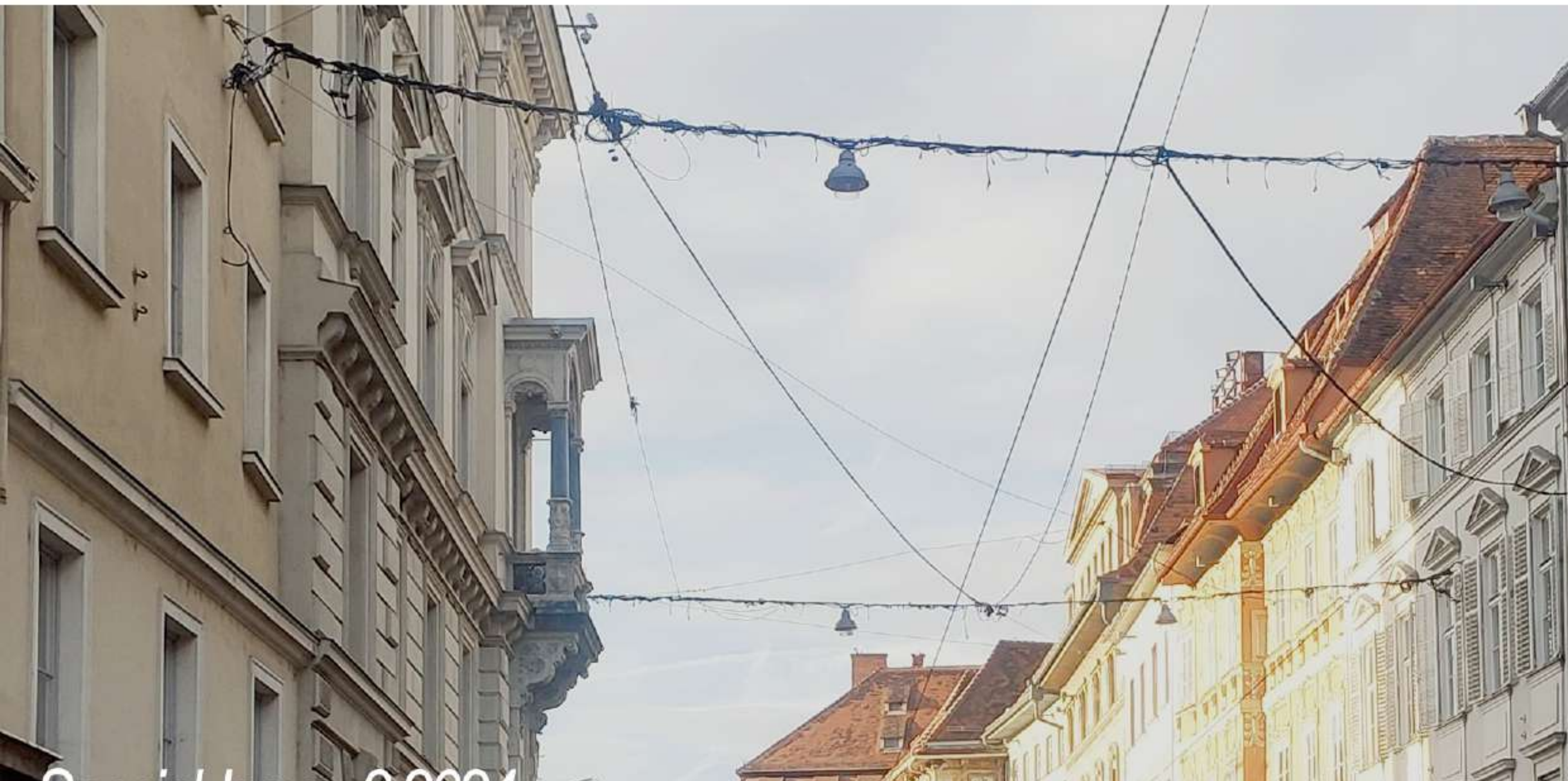

Special Issue 3.2024

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

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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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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).

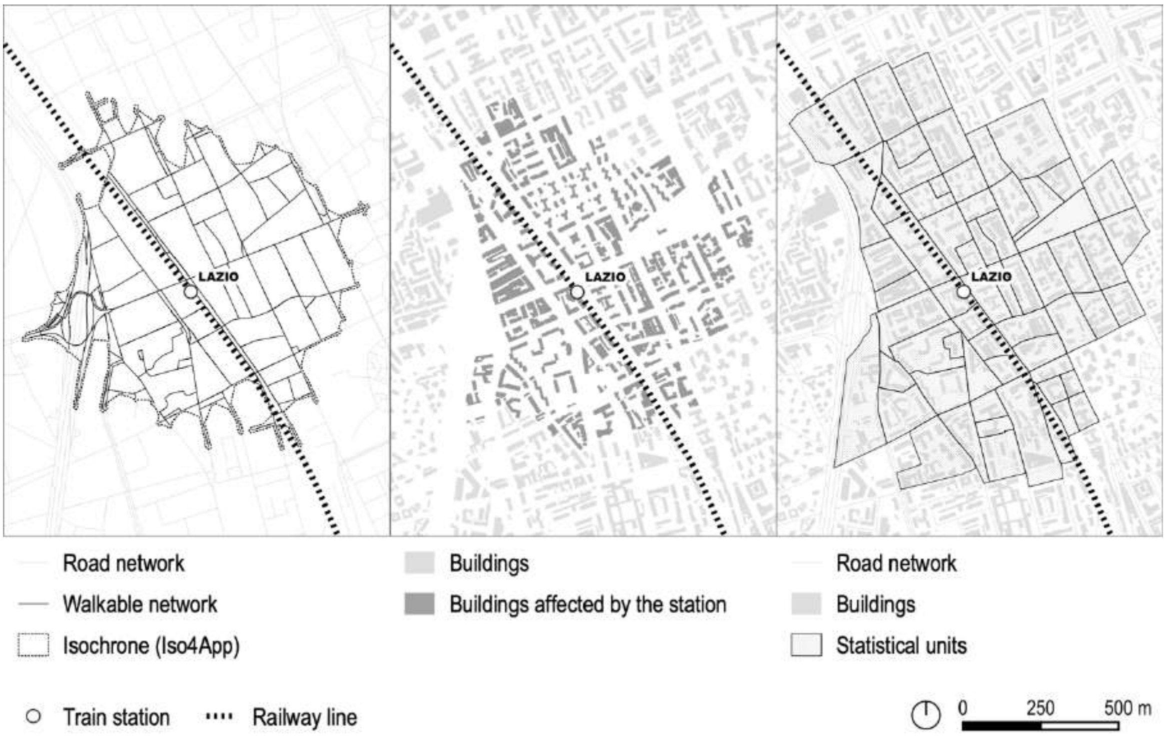

Fig.1 The main elements for the definition of the catchment area: the 7-8 minutes walking network (left), the built environment around the station (middle) and the statistical unit boundaries (right)

We finally established the catchment areas by hand drawing the boundaries of the isochrone (see Fig.2).

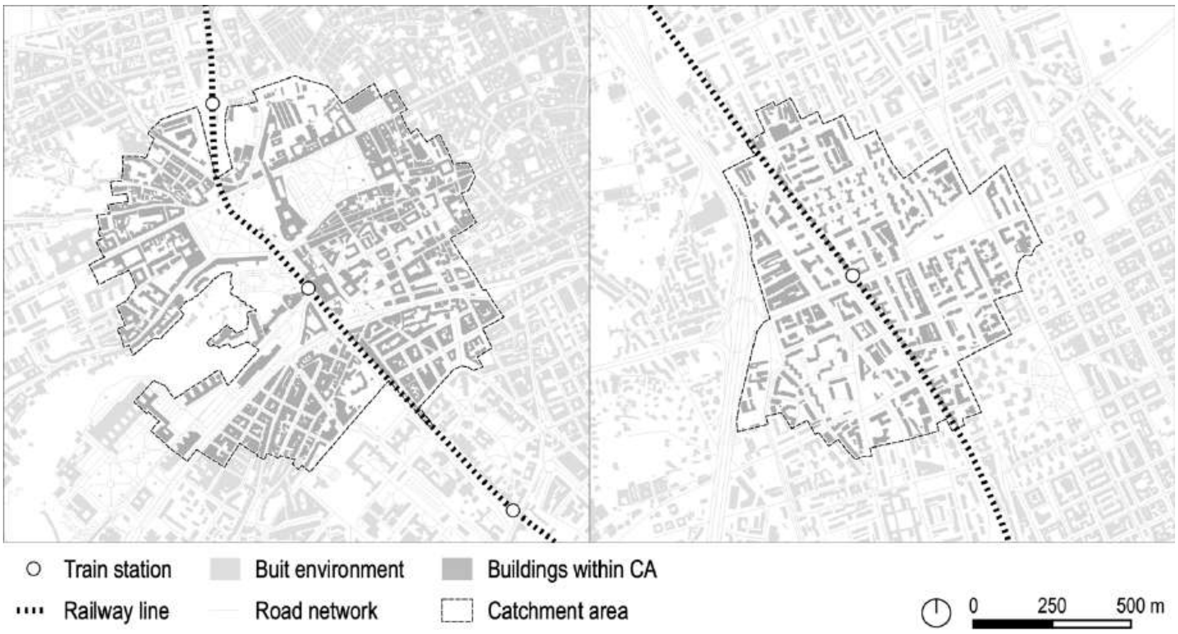

Fig.2 Two examples of the final hand drawn catchment area: the cases of 'Orleans' (left) and 'Lazio' (right)

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).

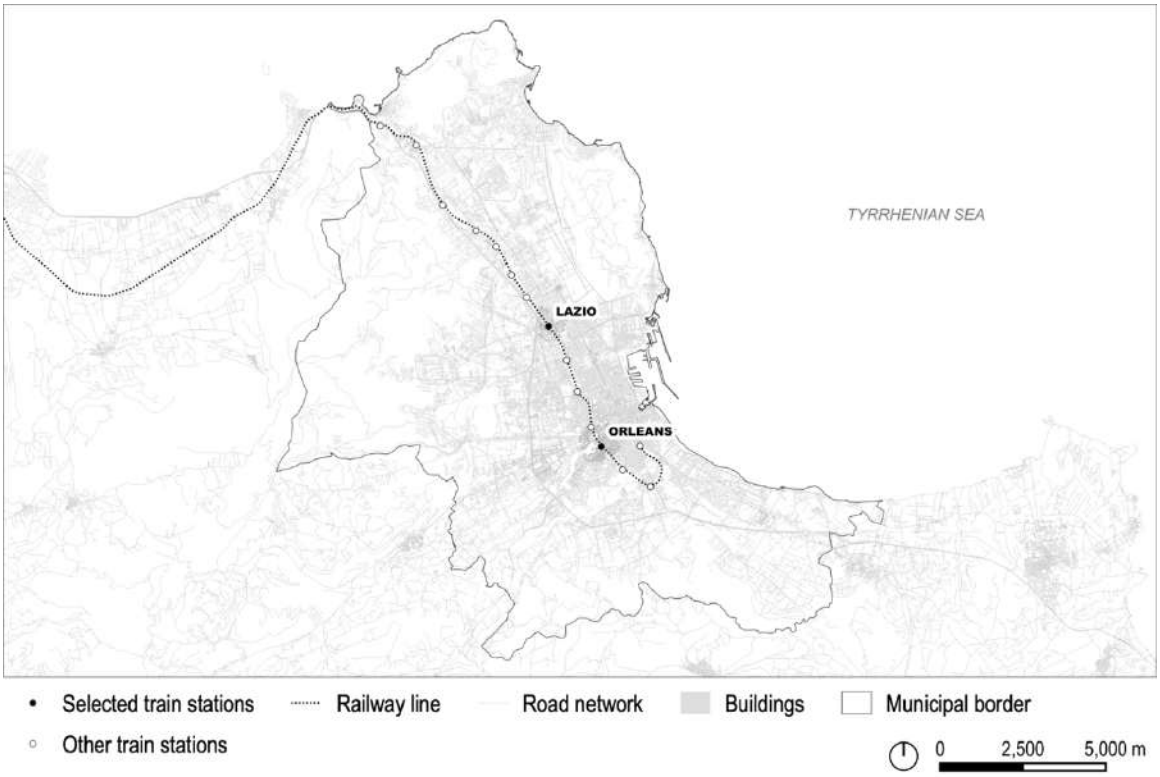

Fig.3 The location of the 'Orleans' and 'Lazio' train stations

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 19^{th} 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.

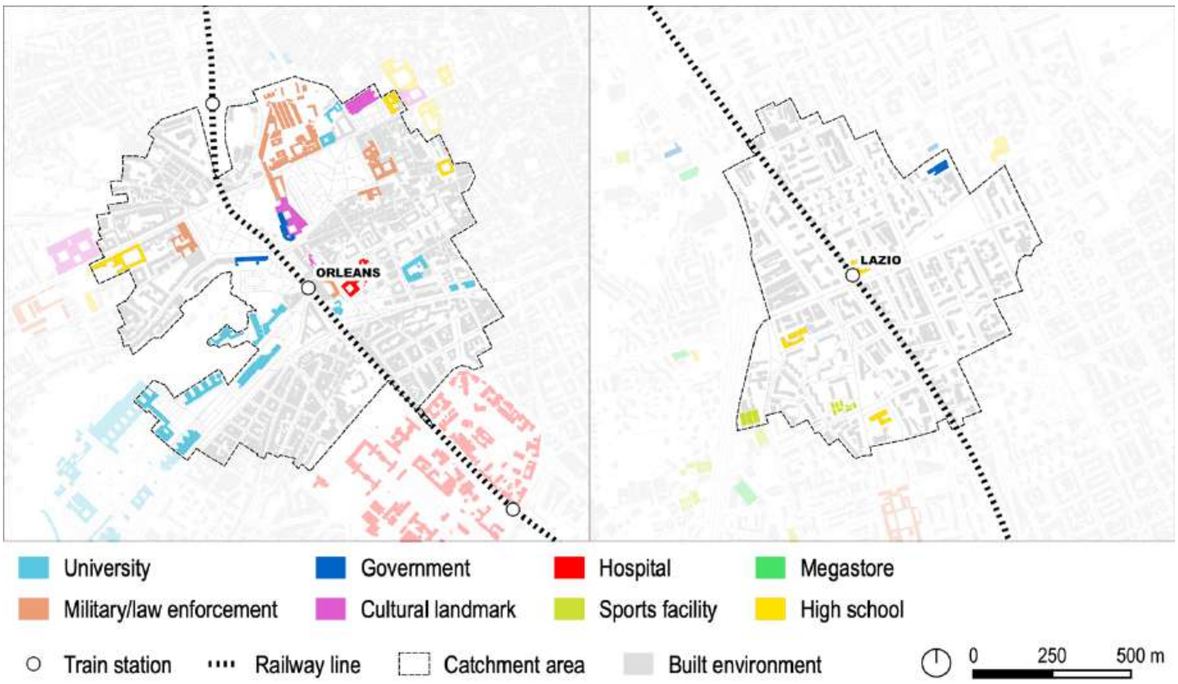

Fig.6 The distribution of city-level functions of the 'Orleans' and 'Lazio' catchment areas

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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Fig.7: elaborated by the authors.

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