Integrating the TOD and 15-Minute City Concepts in the Analysis of Rail Station Areas: A Methodological Approach for a Case Study in Palermo (Italy)

Elif Sezer, João Igreja, and Ignazio Vinci

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. This chapter 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 defines the socioeconomic profile of the area, analyzes the state of the built environment with specific attention to accessibility to services and walkability, and identify strategies for future planning and design processes. The chapter is divided into five sections, including the work's theoretical framework, the description of the case study, and a methodology section explaining the indicators used for the analysis. In the two final section, we present the findings from the analysis and critically outline the potential of this approach for future investigations.

Keywords 15-minute city · Transit-oriented development · Pedestrian catchment area

1 Introduction

Transit-oriented development (TOD) and 15-minute city (15mC) are concepts that—in different ways and times—have widely influenced the planning debate. Originating from the movement against car-dependent urban development in the USA [1, 2], transit-oriented development is an approach that seeks to integrate transport and land use planning to achieve greater accessibility to relevant urban

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functions while increasing the efficiency of public transportation by densifying population and activities around the transit nodes [3, 4]. Optimal to the TOD concept are urban settlements where high-density, mixed-use areas with residential, business, and leisure spaces are located within a 10-min walk distance of a transit station [5]. After the pioneering experiments in the USA [6], focusing on central station areas of metropolitan regions, the TOD concept now embraces a variety of projects with different aims and geographical locations, including suburbs and lower density urban settlements [7].

Revived as an urban recovery strategy during the COVID-19 pandemic [8], the 15-minute city concept is more concerned with accessibility to basic services for the citizens than large-scale connectivity and commuting typical of TOD experiences. Key elements of the 15mC approach to district regeneration are proximity, diversity (both social and functional), and, first of all, walkability. Emphasizing the sense of place and community, the 15mC concept has been associated to other neighborhood planning paradigms of the past (e.g., Perry's "neighborhood unit" [9]), while others have highlighted its search for temporality and flexibility in the adaptation of urban spaces [10].

Beyond these differences, the planning solutions advocated by both the TOD and 15mC concepts are grounded on a wide base of common guiding principles [9, 11–13]. First of all, their effectiveness requires in both cases the existence of a built environment with a density of diverse functions and amenities, without which neighborhoods would not be attractive either to residents and to city-users moved by public transport. Accessibility to these functions is also highly relevant to both paradigms, which should be guaranteed through their proximity to dwellers' homes, the availability of quality public space and walkable streets. Efficient connections to the secondary mobility network (e.g., shared mobility) is also highly relevant to these concepts, to avoid the use of car or secure first/last miles connectivity to the transport network if necessary.

With this conceptual framework on the backdrop, the objective of this work 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 analysis focuses on the area surrounding the "Orleans" station of the metropolitan rail service that connects Palermo's central station to the airport. This station gives direct access to high-ranking public functions, such as the university campus and the regional government headquarter, as well as to major landmarks of the old town.

The assessment criteria adopted in the analysis—with indicators ranging from the social structure to the density of urban functions within in the area—allow defining an integrated description of the context with a double objective: first, to identify the strengths and weaknesses of the district around the station in order to improve accessibility and the quality of public space; second, to make a comparative analysis of the metropolitan rail stations in order to provide guidelines for a TOD approach to urban planning. The analysis to achieve this last objective will be implemented in a second step of the research and will not be treated here.

Accordingly, research questions of this work include, among others, which elements of the place are useful to define the attractiveness of a transit node in a highly complex built environment? To what extent quantitative and qualitative indicators can be merged to describe the place–node interaction? Not least, how this knowledge can be turned into policy guidelines?

The chapter is structured as follows. In Sect. 2, we describe the case study in the overall context of the city's mobility system, historically affected by the low effectiveness of public transport and car dependency. In the subsequent section, we describe the methodology to identify the boundaries of the area under observation, the set of indicators to measure its attractiveness to city users, and the way indicators are normalized in order to get indexes useful for comparative analyses.

With the help of maps derived from indexes and additional spatial analyses, in Sect. 4, we provide a portrait of the case study area, highlighting the strengths and weaknesses around the attractivity/accessibility nexus to guide future interventions in the public space. In the conclusive section, we explore the potential of the applied methodology in the following two directions. On the one hand, to expand research to other stations of the transit network in order to allow a more systematic comparison among different realities and a wider set of policy guidelines for future urban/transport planning. On the other, 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 Case of Palermo

Palermo is the capital of the Sicilian region and the fifth largest Italian city. According to the national census (Istat), its population in 2023 was 630,167. Despite a population loss over the last decades toward the midsized neighboring towns, the core of the city is the daily destination of thousands of commuters as a result of the high density of amenities and functions (see Fig. 1). At the same time, the city has undergone many spatial changes since the 1990s due to new policies being implemented by different local governments, driven by national and European funding opportunities. Particularly interesting was the focus put by local authorities on more sustainable mobility strategies and the effort to rebuild the local identity of the city, which resulted in many investments in deprived neighborhoods and public transportation [14]. The latter aspect has been of key relevance once the city is a clear example of a car-dependent context, listed for several years among the top most traffic-congested cities of Europe [15]. This can be seen as a consequence of the underdeveloped transportation system, a chronic lack of investment in crucial mobility infrastructures [16] as well as of the scarce use of public transport. [17].

Change in the public mobility system took a significant step forward in 2002 with the approval of the "Integrated Plan for Mass Public Transport." This process was later strengthened in 2013 with the launch of the first "General Urban Traffic Plan" and in 2017 with the "Sustainable Urban Mobility Plan." These last

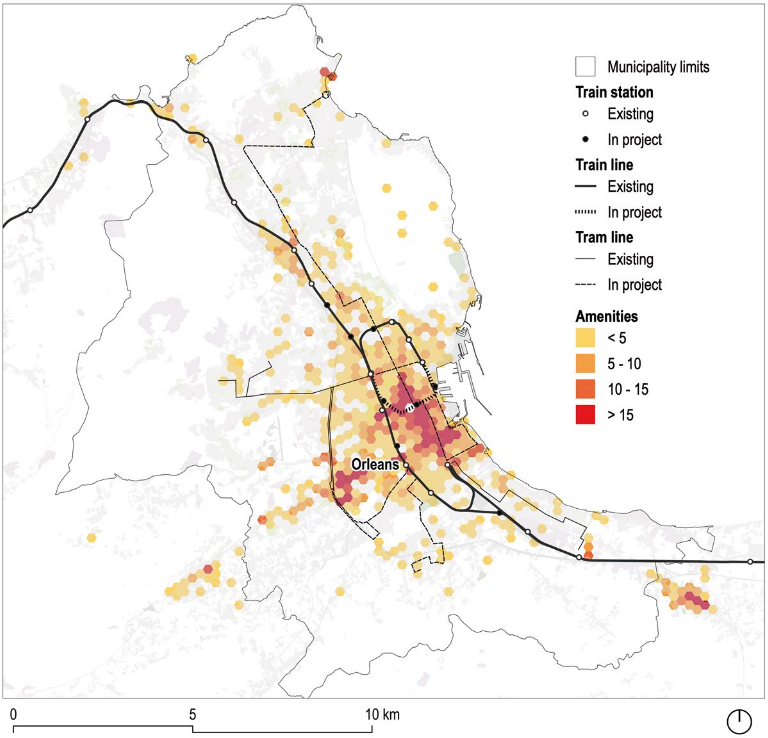

Fig. 1 The distribution of amenities per 5.4 ha and the rail network of Palermo. (Source: authors)

instruments, particularly, sought 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, establishing a wide limited traffic zone coinciding with the old town.

The city's rail network received considerable attention with the abovementioned "Integrated Plan for Mass Public Transport" that combined both new and previously planned projects. These included (see Fig. 1) (a) the redevelopment of the existing railway line into a metropolitan service (railway bypass); (b) redevelopment of an urban railway into a railway ring; (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 first three tram lines was completed on schedule and the tram system will be further developed with additional three lines now under construction.

Regarding the two railway interventions, the implementation has faced several setbacks and part of the infrastructure is still under construction. The implementation of the railway ring—a single track underground line with 8 stops, for a total length of approximately 7 km—has been affected by financial issues of the constructor, and the full completion is now expected in 2029. The rail bypass—30 km of double track line that will connect the airport to the central station—is largely in operation, but various financial and geological issues have slowed down the completion of three underground stops in the city center. This infrastructure, which is among the largest projects ever funded by EU's structural funds in Italy, is already of key importance for metropolitan commuters, and the station targeted by our case study ("Palazzo Reale-Orleans") is among the busiest of the entire railway lines.

3 Methodology

3.1 Definition of the Catchment Area

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 fulfill the different approaches taken. Given the purpose of this study, we focused on the areas that can be covered in approximately 7–8 minutes by walking. Most of all, the reasoning behind this choice relates directly to the specific context of Palermo, including that a 7–8-minute walk can be considered an acceptable time to access/egress the train stations; on average, it takes around 15 minutes to walk between consecutive nodes of the metropolitan rail bypass line; the 7–8-minute distance lies roughly in the median of 15 minutes and is halfway between 5 and 10 minutes.

We considered as starting points the different train station exits and a default speed of 5 km/h. To delimit the catchment area of the node, first we determined 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, thereby making the method more easily reproducible. Secondly, we established the station's catchment area by hand-drawing the boundaries of the resulting isochrone (see Fig. 2).

During this process, we not only considered the built area, but also the limits of the Italian national statistics (Istat) census units, and carried out a comparison with isochrones calculated using online API services. As we shall see below, by taking these aspects into account, it was possible to provide a better integration with the characterization of the area using quantitative and qualitative indicators.

3.2 Evaluation Indicators for Social, Functional, and Environmental Features

As mentioned in the introduction, when it comes to the planning dimensions, both TOD and 15mC concepts are grounded in many common guiding principles. This was taken into account in the selection of qualitative and quantitative indicators (see

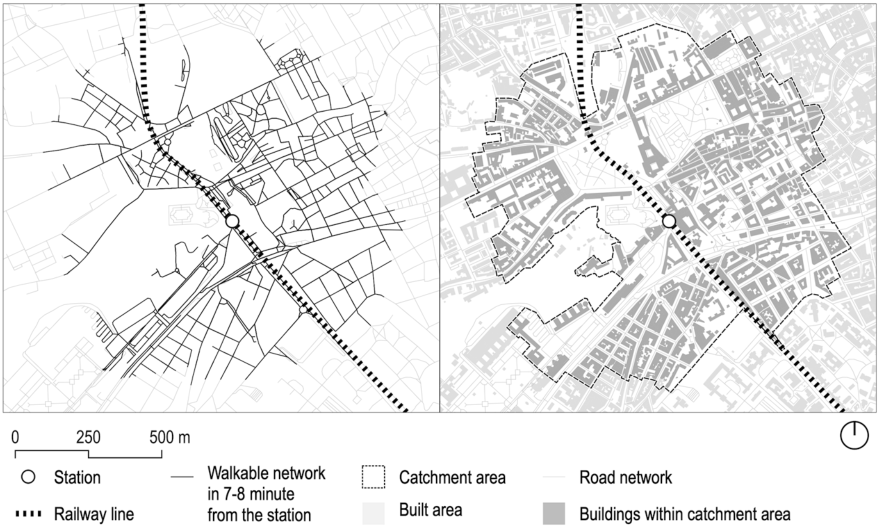

Fig. 2 The 7–8-minute walking network (left) and the catchment area of the "Palazzo Reale-Orleans" train station (right). (Source: authors)

Table 1) that allow characterizing the catchment area in terms of density, functional diversity, traveling and accessibility, street quality, social diversity, digitalization, and flexibility.

Due to the quali-quantitative approach of our methodology, similar to other works in the literature [18–20], 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 describing its housing conditions. These types of indicators are based on statistical data at the level of census units, a factor that allows micro-scale observation and easier results' comparison 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 to highlight the density and distribution of urban functions within the district, 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 derived from a quali-quantitative assessment of the road conditions is mapped in order to render a spatial representation of the condition that may affect accessibility from and to the station.

Given the walkability and accessibility objectives of the study, the street quality assessment constitutes an important part of the analysis. To that end, and keeping in mind that there is little control over determinants such as land use and density patterns, a set of micro-scale indicators were chosen for the evaluation (urban design attributes) regarding the safety and comfort of pedestrians [21, 22]. These included pedestrian–road ratio, vegetation, lighting, slope, speed limit, and traffic restrictions that were individually graded, summed, and normalized to provide the final classification for each street.

Table 1 The principles of TOD and 15-minute city concepts, the set of analytical indicators, and the respective values for the case study: city and "Orleans" catchment area

TOD	15mC	Indicator name	Palermo	"Orleans"
Scale and density	Proximity Density	Population density Housing density Vacant houses	40.3 pop/ha 17.8 houses/ha 14.3%	106.0 pop/ha 52.7 houses/ha 26.9%
Variety and complexity Car movement and parking	Mixed-use Diversity Flexibility	Availability and spatial distribution of city-level functions	Data obtained from the spatial analysis maps, for the catchment area	
		Used buildings	96.1%	92.8%
Connections Transit in the urban pattern	Connectivity Accessibility Modularity	Commuting "outward" Commuting "within" Public transport: Bus stops Bus routes	3.7% 96.3% 1552 114	3.2% 96.8% 28 30
Public spaces for human use Safety Pedestrian/cyclist orientation	Human-scale design Livable public spaces	Pedestrian–road ratio Slope Lighting Speed limitation Traffic restriction Vegetation	Data obtained from the spatial analysis maps, for each individual street	
		Bike-sharing stalls	42	2
Diversity	Diversity	Non-national residents Unemployment rate Old-age dependency	3.0% 11.5% 34.4	5.8% 11.9% 27.5
Smart mobility	Digitalization	Car-sharing points	91	3
Timeframe programming	Adaptability	Buildings in poor state of conservation	26.6%	56.2%

4 Insights from the Analysis

The methodology presented above was applied to the "Palazzo Reale-Orleans" train station to portray its strengths and weaknesses in terms of attractivity/accessibility, and eventually provide inputs for future policies and planning decisions. After delimitating the stations' catchment area (159 hectares), it was possible to see that the population density is high, with 106 inhabitants per hectare (2.6 times more than Palermo) and a housing density of 53 houses per hectare (3 times higher than the city). With regard to the characteristics of the built environment, although 56.2% of all 1,493 buildings did not present an acceptable state of conservation, their occupancy rate was very high, at 92.8%. Moreover, 26.9% of the dwellings are vacant, and in comparison with the city there are 1.87 times more nonoccupied houses in the catchment area.

With respect to the daily commuting habits of the residents, the great majority travel within the city (96.8%) and 3.2% travel toward neighboring towns. In addition to the train station, the public transport system available in the area includes 28 bus stops and 30 bus routes. Moreover, as regards "diversity," of the total number of

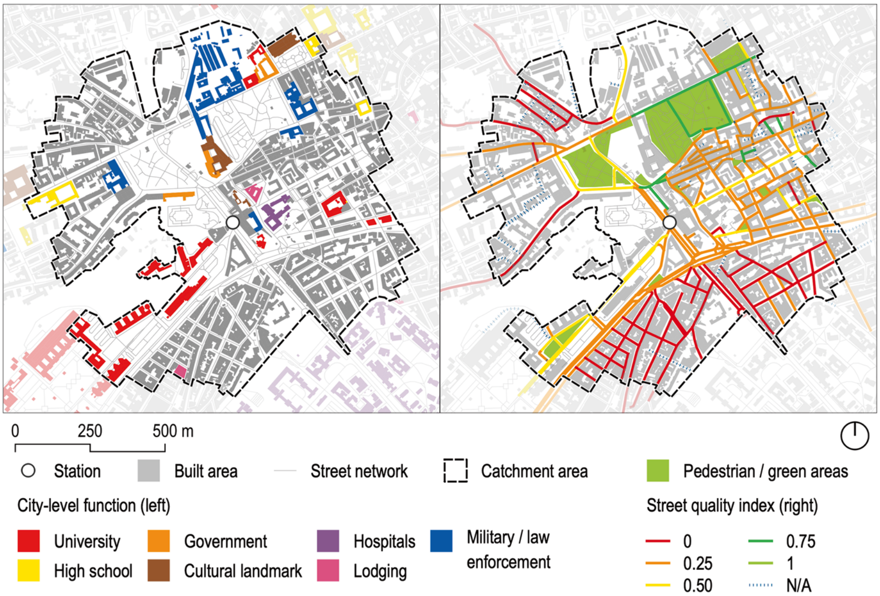

Fig. 3 Analysis of the catchment area: the city-level functions (left) and street quality (right). (Source: elaborated by the authors)

residents in the area (16,906) 5.8% are foreigners (a value 1.94 times higher in comparison to the city), and there is an unemployment rate similar to that of the whole city (11.5% and 11.9% correspondingly), and a ratio between the individuals older than 64 and those in the working-age population of 27.5 (a value 0.8 times lower than the city).

The observation of the availability and spatial distribution of city-level functions in the catchment area shows that it is possible to reach many attractivity nodes (see Fig. 3), 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 do not ensure the most adequate walkability conditions. The pedestrian–road width ratio is typically lower than 30% and for the most part, the pavement width is not suitable for 2–3 people to pass one another or to walk in groups [21]. Regarding comfort, lighting is available on all streets; however, there are few streets with speed limits for vehicles that negatively affect the walking pleasure and safety. On the contrary, traffic restrictions are available on a comparatively higher number of streets. This is because the catchment area comprises part of the "traffic-limited zone" of the Old Town. Vegetation is mostly scarce, except for certain arterial roads and green areas (public gardens and squares). There are no slope variations that pose issues for walking. In terms of shared mobility, there are two bike-sharing stalls that could benefit from being closer to the station, and it is possible to reach three car-sharing areas.

In short, the analysis indicates that active mobility plans should be better integrated with transport and land use plans to create a coherent relationship between urban functions and a well-connected pedestrian network to decrease car dependency.

5 Conclusion

The added value of the research presented in this chapter is twofold. On the one hand, it provides the first integrated analysis of the city–transport interaction around one node of the largest mobility infrastructure being built in Palermo. The analysis builds upon existing methods in the literature [18–20] and tries to combine quantitative and qualitative indicators with spatial analysis and on-site observation. Secondly, it seeks to explore interactions among the TOD and 15mC paradigms under an analytical perspective by looking at the rail station as the epicenter of mobility opportunity for different kinds of users, including dwellers within a 7–8-minute walking radius. To this end, the built environment around the transport node has been scrutinized for its functional profile (typical to TOD approach), but also for other more intrinsic values, such as social diversity and quality of public space (proper of the 15mC concept). For that purpose, the case study showed that the set of indicators selected provided a substantial amount of inputs. However, for future developments we consider making slight changes to the array of indexes and ranking system to prevent ambiguity and simplify the method. Furthermore, the intention to develop an easily replicable approach was undermined by the shortage or unreliability of certain data (e.g., statistical information, street features). This issue needs attention and further revision.

The main limit of the research consists of the lack of a comparative perspective at the city/metropolitan scale that will allow to further refine the methodology in response to local situations not found in the present case study, and most importantly to return a differentiated territorial scenario to give spatial and transport plans more comprehensive guidelines. It is worth reminding to give value to our investigation that no systemic analysis still exists on the impact of the transport system on city's development, in a context where other relevant investment on the transport system are still under implementation.

The next development of the research, thus, will consist of the application of the methodology to a set of station areas of the metropolitan rail bypass with diverse social, functional, and physical structure, with the perspective to expand the analysis to other transport networks and a city-wide dimension.

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