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Transportation Research Procedia 69 (2023) 536–543

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 3rd International Conference on Transport Infrastructure and Systems (TIS ROMA 2022), 15th-16th September 2022, Rome, Italy

The "15-minutes station": a case study to evaluate the pedestrian accessibility of railway transport in Southern Italy

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Abstract

The recent sustainability challenges that our world is facing have raised, more than ever, the attention to the mobility of passengers and freight in the European and international agendas. The energy transition that has begun globally requires identifying and adopting safe, resilient, and increasingly sustainable mobility solutions. In this perspective, the modal split of passengers plays an essential role. One of the main encouraged policies is to promote an efficient mass rapid transit in urban and suburban areas. More in detail, when considering rail transport, it is necessary to analyze and evaluate the role of stations from at least two points of view: i) the ease of access to the station; ii) the opportunities that can be easily reached in its surroundings, following the concept of the "15-minutes" city. These two issues should be properly addressed to guarantee the role of railway stations as an access point to the transport system and an infrastructural element that can enhance a territory. Starting from these considerations, this research proposes a GIS-based methodology able to analyse railway stations from two points of view: i) walkability, considering the main functional characteristics of the transport network, and ii) impact on the territory, by identifying the services located in an area corresponding to "15-minutes" distances using active modes. For each railway station, the main activities in a 15-minute walking isochrone can be evaluated, both considering the walking distance on the pedestrian network and taking into account the current walkability of each link based on arc characteristics. This allows to study the accessibility of railway stations based on the current pedestrian network and the potential one with ideal characteristics. The method is applied to a case study located in Sicily (Italy), in the case of some urban stations. The final scope is to design a decision-support framework useful for railway station operators and local decision-makers to support strategic decisions regarding the railway system and the planning of appropriate pedestrian transport networks to increase railway station accessibility.

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Peer-review under responsibility of the scientific committee of the Transport Infrastructure and Systems (TIS ROMA 2022)

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10.1016/j.trpro.2023.02.205

Keywords: 15-minute city; mass rapid transit; sustainable mobility; urban mobility; GIS; transport planning; urban planning; walkability;; Decision Support tool;

1. Introduction

Urban sprawl, observed in various countries around the world, is considered harmful to the livability and sustainability of the city; this situation causes some externalities, including increased private car use, longer trips within the city, congestion and pollution (Glaeser and Kahn, 2004; Bento et al., 2005). From a quantitative perspective, in 2010, about 73% of European citizens lived in urban areas and it is estimated that this percentage may increase to over 80% by 2050 (European Commission, 2017a). In this respect, transport systems for people and goods are considered essential for the economic growth and welfare of a country and for the quality of life in urban areas; transport is part of social cohesion and demographic development. The mobility sector includes a complex network of 1.2 million private and public companies in the EU, employing 10.5 million people and providing goods and services to citizens and businesses. About the environmental impact, carbon dioxide emissions from road, air and maritime transport account for 74%, 12% (excluding non-CO_2 impacts, which are estimated to double the sector's warming impact) and 12%, respectively. Policies to decarbonize the transportation and mobility sector provide an opportunity to combine climate and environmental protection while ensuring economic and social balance (Carnevale and Sachs, 2019). In this context, the European Council has approved an important goal that concerns the countries of the European Union: the target is to become climate neutral by 2050 and reduce greenhouse gas emissions by at least 55% by 2030 (European Commission, 2017b). In addition to the environmental issue there is also the one of safety: every year more than 1.35 million people die on the roads and several million suffer serious injuries with important social costs for the community. In addition, road accidents are the leading cause of death for people aged between 15 and 29, worldwide. The important goal of halving the number of deaths and serious injuries on roads has been renewed towards the “Vision Zero” of 2050 (WHO, 2018; European Commission, 2020).

Fostering travel and mobility towards more sustainable modes of transport, mainly walking and cycling, is one of the best ways to limit the increase in motorization and mitigate climate change (Caprì et al., 2016; Ignaccolo et al., 2018). Finally, reducing cities’ automobile dependence and related energy consumption requires integrating land use and transport planning. In this respect, two concepts play a fundamental role: on the one side accessibility by proximity, i.e. discouraging the use of motorized vehicles and fostering active modes; on the other the 15-minutes city, i.e. an area where people needs are located within a travel distance of 15 minutes. In areas where these conditions cannot be met (e.g. suburban, rural), the presence of a good public transport system can also allow citizens living in peripheral areas to access goods and services in a sustainable way. In particular, the use of railway transport might improve the quality of life, allowing users located in the suburbs or neighboring villages to reach the essential activities quickly and reliably (Giuffrida et al., 2022).

Based on these premises, the aim of this work is to provide an approach to evaluate the accessibility of railway stations by active modes users, both in terms of quality of the infrastructure to access the facility and opportunities and services located in an area corresponding to the 15-minutes city. The proposed approach can be considered a useful decision-support tool that can be used by actors involved in the decision-making process (station managers, municipalities, government departments, etc.). In addition, the method makes it possible to prioritize interventions by identifying situations where it is most urgent to allocate resources to improve accessibility.

The paper is organized as follows: section 2 provides background with reference to the technical-scientific literature, section 3 illustrates the methodology from a procedure point of view while section 4 reports the main results within the case study in Italy; finally, section 5 presents the conclusions.

2. Background

Several scholars have investigated the two important topics of 15-minutes city and accessibility by proximity in urban areas. With reference to the first topic, particular attention is given to the relationship between mobility within cities and urban design, giving rise to a debate on the optimal size and structure of cities (Ewing and Hamidi, 2015; Kirkley et al., 2018). New sustainable mobility models and current planning strategies shift from monocentric city structures to more localized polycentric structures with the goal of increasing the supply of local services, such as schools, public transport alternatives, healthcare facilities, dining facilities, jobs, recreation areas, and retail stores, by creating local areas that are sustainable, inclusive, and walkable within a small distance (Brezzi and Veneri, 2015; Artmann et al., 2019). Some research suggests the need to plan and design pedestrian-scale neighborhoods to improve local accessibility, adapt travel behaviors, and reduce car ownership and travelled distance (Krizek, 2003; Zhang et al., 2020, Carra et al., 2022). Other studies remark the importance of dealing with this topic. Vale (2015) and Carra & Ventura (2020) combined the node-place model proposed by Bertolini (1996) together with transit-oriented development (TOD) planning concepts with the aim of analyzing the level of walkability of train stations. The idea of the 15-minute city is gradually growing in importance both politically and socially: local areas should be designed to be more sustainable, inclusive, walkable, and accessible within a small radius by foot or bicycle. Other studies have applied the idea of the 15-minute city to railway stations, configured as the starting point of the analysis: the railway station represents the "front door", from where users begin their last-mile journeys after getting off the railway (Borghetti et al., 2021a; Borghetti et al., 2021b). The second issue concerns pedestrian accessibility, which becomes a key component of urban transport, although often under-developed in car-dependent cities (Tight et al., 2011; Ignaccolo et al., 2020). The sprawl of the urban structure mainly based on the use of the car and the lack of adequate pedestrian infrastructures limit the spread of pedestrian mobility (Newman et al., 2016). This mode should be promoted for both systematic trips and other reasons through adequate planning, design, and management of seamless pedestrian networks (Arranz-López et al., 2018). To achieve this goal, appropriate decision support tools based on data and analysis can be used, especially in limited resource contexts; in this case, it is possible to prioritize interventions and investments for the development of walkable streets, paying attention to land use (e.g., points of interest). Evaluating the quality of a pedestrian/cycling path cannot disregard the efficiency of the infrastructure, nor the pleasantness of travelling along it. The availability and use of geo-localized data related to active modes demand and infrastructure allowing spatial analysis with Geographic Information Systems (GIS) can help to identify areas in need of interventions through user-friendly maps (Giuffrida et al., 2017, 2020; Gonzalez-Urango et al., 2020; Rossetti et al., 2020). Moreover, the use of open data can play a determinant role in the case of scarce resources. Based on this premise, in this paper we will introduce a GIS-based approach to evaluate the accessibility of railway stations in a catchment walkable area of 15-minutes accounting for the walkability of the pedestrian network. The main novelty of the proposed approach lies in the possibility to evaluate with a unique analysis both the quality of the infrastructure and the accessibility to opportunities; the use of open data reduces the burden of an on-site survey and allows for a quick estimation, useful for a first ranking of priorities of intervention.

3. Methodology

The approach is based on the spatial analysis of the area comprised in the 15-minutes isochrone evaluated on the pedestrian network with origin at a railway station. The analysis was performed using the open-source software QGIS (QGIS Development Team, 2022), an open-source Geographic Information System for visualizing, editing and analyzing geospatial data.

The approach is based on the following steps:

1. Importing of the road network including information on the pedestrian infrastructure for each arc;
2. Computing of the 15-minutes isochrone areas starting from the railway stations on the network, with a constant pedestrian speed of 4 km/h on each arc;
3. Calculation of a new speed on each arc, based on technical characteristics of pedestrian areas (slope, sidewalk width, etc.);
4. Computing of the 15-minutes isochrone areas with the new speed;
5. Comparison of the number of points of interests (POIs) counted inside the two areas.

For the creation of the 15-minutes isochrones, the QNEAT3 (QGIS Network Analysis Toolbox 3) plugin is used. This plugin, written in Python and integrated in the QGIS Processing Framework, allows iso-area analysis, both in terms of distance and time, based on the imported road network, by assigning a default speed or based on a function. In particular, the "Iso-Area as Contours (from Point)" algorithm has been used since the aim is to obtain isochrones starting from specific points (i.e., train stations). The Iso-area is created on the basis of the imported road network and the speed assigned to each arc.

The POIs are retrieved thanks to the use of QuickOSM plugin, a tool to extract geolocated information from the Openstreetmap (OSM) database.

4. Case study and results

The methodology is tested for the city of Catania, a medium-sized city located in the south of Italy (Sicily). The city of Catania has an area of about 180 km² and a population of about 300000 inhabitants. In particular, two urban railway stations were taken into account: Catania Centrale and Picanello (Fig. 1): both facilities are managed by Rete Ferroviaria Italiana (RFI), the main national railway infrastructure manager. We decided to consider these stations for their different characteristics and impact on the territory. Centrale station is located in the urban center and it is the main railway station of Catania; on its front there is a metro station, an urban bus terminal and the suburban bus station. There is also a bike-sharing station and an on-street parking with some spots reserved for car sharing vehicles. In this respect, it can be considered a multimodal transport node. Picanello station is, instead, located in the densely populated district of Picanello; the station has problems of visibility due to its location and the connection with other modes of transport is not guaranteed.



Fig. 1. Centrale and Picanello railway stations in Catania city.

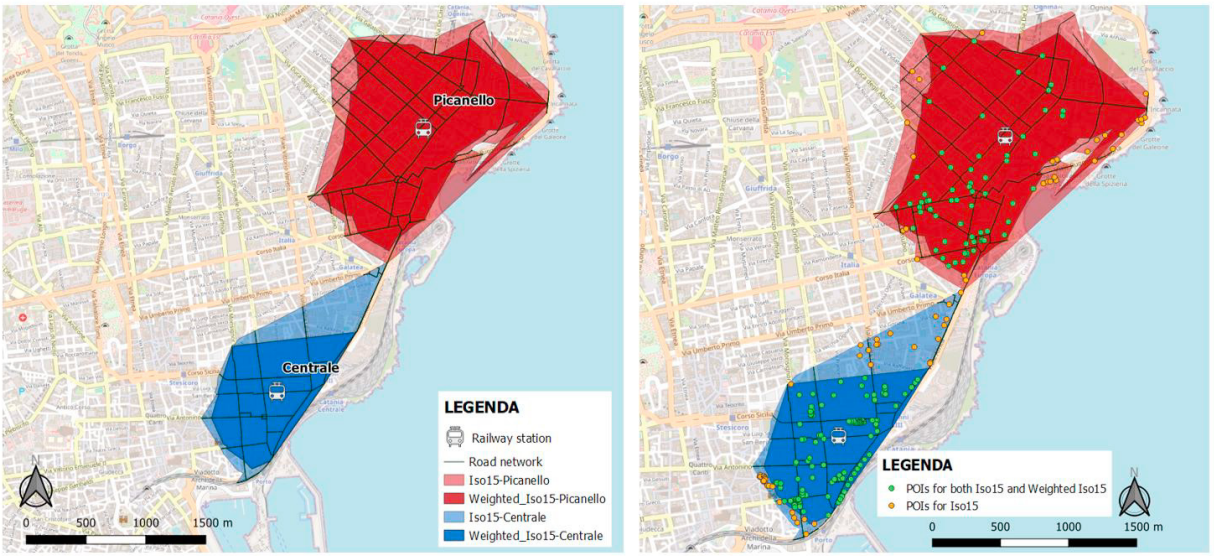
Following the five steps presented in Section 3, the road network of Catania was imported and location of the two considered stations is indicated on the map (Step 1) (Fig. 1). The road network is composed of links with information related to the width of sidewalks and path slope. Step 2 consists of the calculation of the Isochrones corresponding to 15-minutes area (Iso15). These Iso-areas were computed with QNEAT3 plugin using a constant walking speed of 4 km/h, since a speed range of 2-5 km/h is regarded as plausible by the scientific literature (Calabrò et al., 2022) (Fig. 2a). Information on the pedestrian infrastructure has been used to assign a new speed value to each link, according to

the previously defined speed range (Step 3). The rationale behind this approach is that it is plausible to consider a reduction of the speed associated to a poor infrastructure or to a high slope. This is in line with recent research studies that investigated pedestrian walking speeds (Rastogi et al., 2011; Al-Azzawi and Raeside, 2007). Three ranges for sidewalk width and path slope have been assigned with three different speeds, as shown in Table 1.

Table 1. Pedestrian speed assignment according to sidewalk width and path slope.

Sidewalk width [m]	Slope [%]	Pedestrian speed [km/h]
> 1.5	≤ 0	4
0 – 1.5	0 – 6	3
0	> 6	2

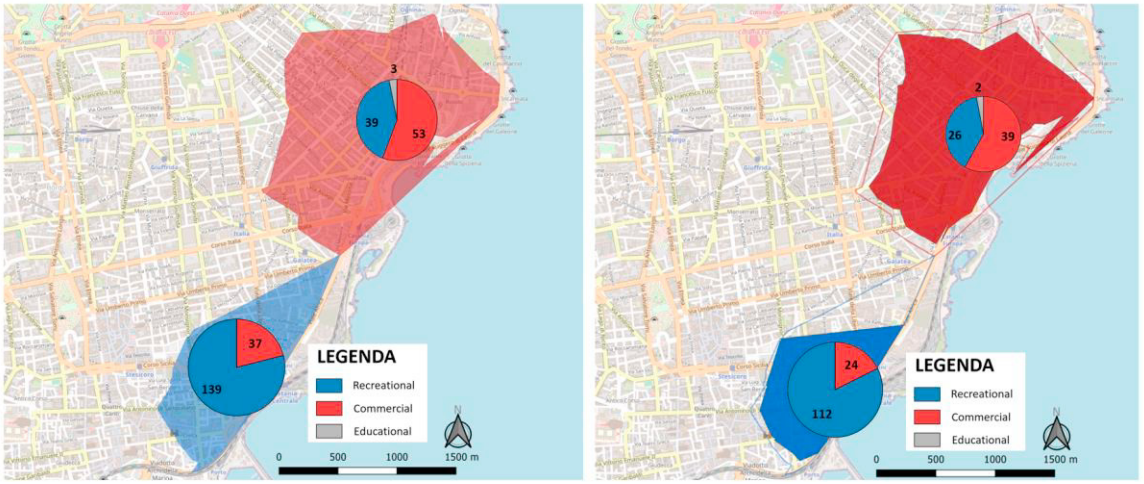
Isochrones using the new walking speed associated to each link are then computed (Weighted_Iso15) (Fig. 2a) (Step 4). Finally, POIs have been imported and counted for both Iso15 and Weighted Iso15 areas through OSM plugin (Fig. 2b) by selecting “amenity” as key (Step 5).



(a) (b)

Fig. 2. (a) Iso15 and Weighted Iso15 areas for Centrale and Picanello stations; (b) POIs for both Iso15 areas.

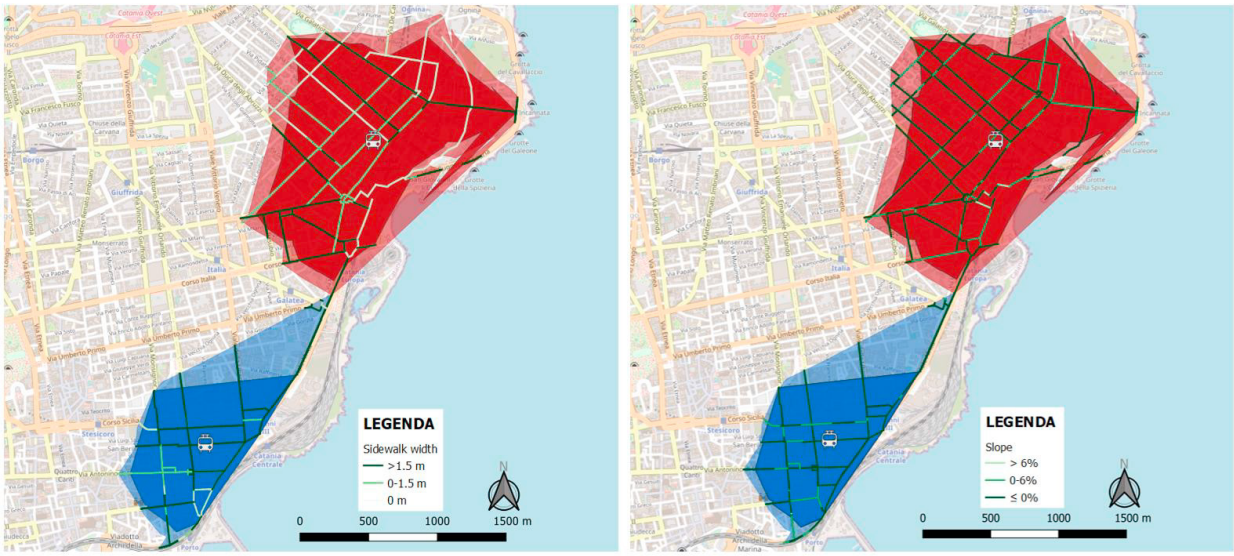
A total of 271 POIs were retrieved for Iso15 areas; the changes in speed due to the quality of the infrastructure lead to a loss of 68 POIs (203 in Weighted Iso15). POIs are classified into three categories: i) recreational (e.g., tourist destinations, restaurants, etc.), ii) commercial (i.e., general services) and iii) educational - schools and university venues. Fig. 3 shows the number of recreational, commercial and educational POIs for Iso15 (Fig.3a) and Weighted Iso15 (Fig.3b) areas. The comparison of the two maps shows that the current pedestrian infrastructure characteristics reduce the number of activities that might be accessed by users of about the 25%. More in detail, the loss in activity accessibility for Picanello station is of about the 30%, with a significant reduction in recreational activities (about 33%). In the case of Centrale station, the loss in activity accessibility is of about the 23%, with a reduction of 35% for commercial activities.



(a) (b)

Fig. 3. (a) Distribution of POIs type for Iso15 areas; (b) Distribution of POIs type for Weighted Iso15 areas.

This points to the need of considering the current characteristics and conditions of the pedestrian network while looking at the actual accessibility of railway stations. Improving the walkability, e.g. by increasing the width of sidewalks, will result in an improvement of the station accessibility. It is worthy of notice that in future research walkability should be based on many other network characteristics and conditions, e.g. traffic conflicts, lightings, continuity of the path (Ignaccolo et al., 2020), but also pedestrian flows, and one should understand the actual impact of these features on walking speeds. Besides, thematic maps like the ones presented in Fig. 4 can help to understand how to improve walkability by acting on specific characteristics, e.g. sidewalk width. In the case of Catania, sidewalk width is insufficient in many cases, therefore it is important to improve it to enlarge the catchment areas and number of POIs of railway stations.



(a) (b)

Fig. 4. (a) Sidewalk width; (b) Path slope.

5. Conclusions

This paper presented a spatial analysis of the pedestrian accessibility of railway stations, following the approach of the "15-minutes stations". In this respect, for railway transport operators to attract more users, it is important to focus on the attractivity of the railway station based on the potential activities that can be reached considering a walkable distance. Walkability depends on the characteristics of the pedestrian network. Therefore, one should consider the current conditions to evaluate the actual number of opportunities that can be reached by the railway station. Based on this, we propose the evaluation of accessibility based on the number of points of interest (POIs) that are located in a 15-minute isochrone. The method is tested in two urban stations in Catania (Italy), showing that by improving the pedestrian network conditions, 25% more activities would be reached by the railway stations. This points to the importance of improving the surrounding area and transport network of a railway station to increase its accessibility and attractivity.

In this respect, the practical implication of this study is to provide a planning-support tool able to visualize the accessibility of railway stations, in terms of activities that can be reached in a walkable distance, while taking into account the real walkability conditions of the area surrounding the stations. This will allow to have a simple indicator, based on isochrones, of the effectiveness of any intervention aimed at improving walkability.

The proposed method is replicable, modular, and expandable. It can also be replicated in other contexts at different levels of detail (depending on the needs of the analyst). It also allows for the representation of specific parameters and indicators depending on the type of analysis and makes it possible to insert new parameters for assessing accessibility.

Acknowledgement

The work was partially supported by the project "WEAKI-TRANSIT: WEAK-demand areas Innovative TRANsport Shared services for Italian Towns" (unique project code: E44I17000050001) under the programme "PRIN 2017", by the project of M. Le Pira "AIM Linea di Attività 3 – Mobilità sostenibile: Trasporti" (unique project CODE CUP E66C180013890007) under the programme "PON Ricerca e Innovazione 2014-2020–Fondo Sociale Europeo", Azione 1.2 'Attrazione e mobilità internazionale dei ricercatori', and by the project "ADDRESS" under the University of Catania programme "PIACERI Linea 2".

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