A Two-Steps Analysis of the Accessibility of the Local Public Transport Service by University Students Residing in Enna

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Abstract. The attention to a sustainable environment and mobility has increased significantly in the last two decades, directly linked to human and economic activities. Such a sustainable agenda can only be implemented through a strong interaction between the economic actors involved, aware of the transport choices and their consequences. Similarly, a university campus in an urban context requires in-depth studies on the balance between supply and demand for transport dedicated to the university population. These users have different daily or weekly travel times from those of the resident population and travel frequencies that are not always constant. The result is a highly segmented demand for local (LPT) and regional (RPT) transport, which needs to be investigated to improve services and infrastructures and to ensure that all university students can choose sustainable forms of transport and give up using private motorized transport.

The present research focuses on assessing the characterization of the resident and university population with domicile in Enna Alta and analysing the public transport offer that allows the connection between Enna Alta and Enna Bassa. Specifically, this study considered a double-step investigation of accessibility in topological and spatial terms by implementing QGIS and isochrone calculation. The research is novel as it highlights the implementation of a system that allows easy tracking of accessibility isochrones through the use of open-source GIS software, which in addition to being free, is highly adaptable to different technical requirements. Findings suggest that only the northeastern part of the city has good accessibility. Similarly, the connection between upper and lower Enna through the LPT service provides valuable indications to local authorities. These authorities could collaborate with the University governing bodies to implement policies of green commuting, trying to enhance public transport and reduce the number of private vehicles by promoting new forms of shared mobility, such as carpooling or car sharing. The results lay the foundations for further comparative studies and provide a starting point for local transport service managers to optimize the sustainable transport offer and therefore allow a reduction in the use of private transport.

Keywords: Sustainable mobility · Local public transport · University city campus · University student accessibility

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O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14106, pp. 147–159, 2023.
https://doi.org/10.1007/978-3-031-37111-0_11

1 Introduction

Rapid urbanisation has led to a massive transformation of urban space in several European countries in both spatial and social terms [1]. It is closely related to the travel frequencies and modal choices of users living in or travelling to and from cities. In recent years, we are witnessing the creation of several campus cities in which the percentage of students is substantial concerning the local population [2–4].

Several studies in the literature have drawn attention to the different modal choices made by university students, including more recent choices such as shared mobility. It is crucial to analyse public transport to optimise the movement of several individuals to similar destinations with the same purpose of home-school or home-work. In some contexts, such as China, higher education has grown much faster than in the past, with an explosive increase in the university population. Unlike Western universities, most Chinese university students have to reside on gated campuses. Their accessibility to public transport and the resulting spatial and social implications have been neglected in the literature.

A study conducted by [5] analysed the concept of spatial accessibility through four methods: proximity-based, gravity-based, population-weighted average, and competition-based, using population data at the residential building level. All results confirmed the presence of spatial and social inequalities in public transport accessibility for university campuses and student populations. The study also found that these inequalities are not directly due to the provision of public transport services but to the closure of gated campuses to external public transport.

A study by [6] determined the factors influencing the quality of public transport service and the student demand for public transport. The study found that convenience is the most important factor for bus service quality, followed by service planning and the bus network. The most important factors influencing the intention to increase bus use are attitude, personal norms and the lack of a private vehicle. All three factors positively affected the intention to increase the use of the au-bus. One factor that had a negative impact was the perceived behavioural control in increasing bus use. Socio-economic factors such as hometown, gender and academic year did not directly depend on increasing bus usage, but had an indirect effect through vehicle ownership.

Several European and non-European states, to be able to implement a series of sustainable policies and strategies under the United Nations' Agenda 2030 and the European Green Deal, have highlighted the need to implement a series of urgent solutions to improve people's quality of life, encouraging, especially in systematic mobility, the use of alternative and more environmentally friendly modes of transport than private vehicles.

Commuting students to and from university campuses has a substantial social, environmental and transport impact. A study in Portugal by [7] analysed the modes of transport used by a group of students in their commute, the potential for switching to more sustainable modes and the respective CO2 re-splitting considering two scenarios: an optimistic one and a more likely one. The results described in this study can help university campus managers and planners to adopt planning policies to make mobility more sustainable.

This study focused on a double level of analysis of topological and spatial types. It is connected to implementing open-source geographic information medium QGIS and considering the calculation of isochrones related to distances between residential areas and local bus stops. This double level of investigation made it possible to emphasise that there is currently no homogeneous spread of the examined context of accessibility to local public transport by university students living in the historic centre.

These results highlight the need to implement more sustainable mobility strategies with a greater spread of transport services to counteract the use of private cars. Specifically, Sect. 2 analysed the growing development of city campuses worldwide and highlighted the main factors influencing university students' use of specific modes of transport. Section 3 focused on the Italian context, and recent studies analysed the demand and supply of mobility for university students prevailing in some regions. In Sect. 4, the double level of analysis was detailed with the methodology definition and implementation of QGIS and isochrones calculation. Finally, in Sect. 5, some considerations and conclusions to the research are presented.

2 Literature Review

The Italian system is composed of a total of 97 university institutions, of which 67 are State Universities. In addition, 19 legally recognised and 11 non-state universities are also legally recognised. Different types of cities (size, location, number of inhabitants) are today home to one or more university campuses located in some cases in the context of the historic centre or, in most cases, in expansion areas [8].

The ability to successfully achieve positive and negative effects from the urban location of these large traffic-generating institutions is crucial for the development of university campuses and the city's liveability. A study conducted at the University of Trieste has shown how transport mode choices are made by teaching and administrative staff and students at the various locations where academic activities occur and how they would be influenced by eight different transport management policies [9].

Numerous universities worldwide and in Italy have adopted initiatives to reduce the environmental impact of the mobility of the entire academic community. A study conducted by [10] in Thessaloniki shows how the walking distance accepted by students to reach the public transport stop can increase if a higher frequency of the service is guaranteed. In [11], it is highlighted how, starting from the study carried out in Moscow, Idaho, low-cost parking allows one to use the car for shorter distances. A study conducted by [12] in the Grenoble Metropolitan region of France classified the studied area according to the various level of active and public transport accessible zone; among the factors influencing accessibility are intersection density and land use. Researchers conducted a study on student mobility at the University of Foggia, in Apulia, to survey and assess the mobility routines of community members (students, academic and administrative staff). Through the administration of a questionnaire, several useful contingency tables were defined for the statistical description of the main means of transport used by the members of the university community and their emissions [13].

Several research studies in recent years have underlined the factors that most influence the modal choices of this target group. A study by [14] examined the travel habits

of students and staff of a medium-sized public university campus in a peripheral area of the city of Varese (northwest of Italy), far from the suburban railway and bus stations and with many green spaces. The main results highlight the crucial role of the proximity of public transport (bus and train stations) in both short- and long-distance travel. Other factors influencing the choice of transport mode include the age of commuters and, to some extent, gender, frequency and length of trips. In contrast to the results of the empirical literature on urban colleges, we found a positive correlation between distance and train use.

Many studies, both in Italy and abroad, have focused on the assessment of travel time to estimate accessibility to university campuses through both local public transport and shared mobility systems [15, 16]. Some studies have analysed both intra- and extra-urban university travel by considering both trajectories using special GPS devices [17] and, more important, student mobility trajectories between macro-areas and disciplinary areas and emphasising the influence of such travel by considering previous travel and mobility choices related to education at higher education institutions [18, 19].

A few studies have focused on analysing the accessibility of city campuses considering the implementation of QGIS and the calculation of isochrones. This type of investigation requires data related to the dislocation of infrastructures and the analysis of the housing locations of the target users to be analysed as well as correct and up-to-date information on public transport services in the examined area.

Starting from this, the present work set itself the objective of understanding the possible propensity of university students living in the historical centre area in Enna in Sicily to use local public transport to reach the university campus. Therefore, as a first step, the research investigated the distribution of inhabitants and university students in upper Enna in Sicily by reconstructing the current layout based on territorial information support. In the meantime, the present infrastructures were analysed with particular reference to the distribution of urban bus stops and the local public transport offer was analysed, which allows the connection of the area of Enna Alta (on the top of the plateau) with the context of the university campus located at the base of the plateau. Finally, the distance of the main areas inhabited by students with the urban bus stops was estimated through the estimation of isochrones from which it is possible to understand how distance can influence the modal choice of public transport.

Therefore, paragraph 2 defines the methodology conducted while paragraphs 3 and 4 analyse the case study results and highlight in the concluding part possible directions for strategies to improve public transport services and better urban and mobility planning that can take into account commuter population groups such as university students.

3 Methodology

The analysis developed in this article aims to propose a methodology for evaluating the collective public transport service in an urban reality in which the distribution of student residences and the public transport offer is known. The proposed methodology is divided into two steps:

– analysis of the territorial distribution of students;

– analysis of the accessibility of the LPT supply system.

To analyse the territorial distribution, a study is carried out related to the possibility of clusters of areas, defined according to the demand criterion to be analysed. To do this, the Moran scatter plot is used. The performance of a variable in the x-axis is represented, and that of its spatial lag in the y-axis; in this way, the presence of spatial auto-correlation for the variable can be identified.

From the Moran scatter plot, it is possible to determine Moran's MC coefficient, a spatial autocorrelation coefficient that makes it possible to verify the existing correlation between a variable and its spatial lag [20, 21]. It is defined as:

$$MC = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} wij(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{N} (x_i - \overline{x})^2} \quad (1)$$

where:

N is the number of spatial units, with indices i and h;
x is the variable considered;
x- is the mean of the variable x;
wij are the elements of a spatial matrix, with wii=0;
W is the sum of all wij.

For the analysis of LPT accessibility, different approaches are proposed in the literature [22–24]. Attention has been paid to accessibility by persons with disabilities [25, 26]. Among the mathematical tools in the literature for the analysis of LPT accessibility, one interesting tool is that of isochrones [27]. Isochrones are used both for the analysis of the existing network [28] and for the evaluation of improvement interventions [29].

The paper intends to propose a methodology that considers pedestrian isochrones to evaluate the accessibility of the LPT system, discretizing the service by lines and user categories. It is proposed to evaluate the pedestrian isochrones related to each stop of each line, measuring the rate of a population segment included. The objective is to have a tool to compare the lines with each other according to the population groups most affected, relating them to the spatial distribution analysis carried out previously. Consider the study area characterised by a number $n = 1,2,\ldots, N$ of zones, each characterised by an area An and a population P_n. Consider a public transport system characterised by many lines $l = 1,2,\ldots, L$. We define the area generated by the union of the areas delimited by the isochrones obtained from the LPT stops belonging to line l. For each area il relative to line l, it is possible to evaluate the area obtained from the intersection with the generic A_n; the intersection area is defined as $A_{n,l}$. For each area n we consider the population P_n uniformly distributed within the area. The estimation defined $P_{n,l}$ as the share of the population P_n contained within the area $A_{n,l}$ evaluated as:

$$P_{n,l} = \frac{A_{n,l}}{A_n} P_n \quad (2)$$

The total population P_l within area il is obtained as:

$$P_l = \sum_{n=1}^{N} P_{n,l} \ \forall l \quad (3)$$

4 Case Study and Results

4.1 The Territorial System

The case study focuses on the city of Enna, an Italian municipality and provincial capital, located in the central part of Sicily. About 25,000 inhabitants inhabit the city, and there are also about 8,000 university students. The built-up area is divided into two geographically clearly separated areas: the historic urban centre (Enna Alta), with a resident population of about 15,000 inhabitants (Source: ISTAT), located on a plateau and the expansion area Enna Bassa, where some of the most recent structures are located, in particular the University.

The characteristic of the case study makes it particularly interesting: the presence of the University and numerous educational institutions located in lower Enna, against a majority of the population living in upper Enna, makes the optimisation of LPT vital. In the case study, the LPT lines connecting Enna Alta with the outside are analysed; their accessibility within the Enna Alta Study Area is evaluated. The aim is to assess whether the lines for home-study trips are accessible.

4.2 Spatial Distribution

The province of Enna is located in the heart of Sicily and its capital has been identified as the island's geographical centre; despite not having access to the sea, it has a rich natural heritage. It extends over 2,562 sq km (10% of the regional area), the fifth Sicilian province in territorial extension and the ninth in inhabitants.

The province of Enna, physically located in the island's centre, represents an important road link between three large areas of Sicily: the eastern, central and north-western parts. It is crossed by the motorway network, which directly connects two large municipalities in the region, Palermo to Catania and which at the same time facilitates travel between several municipalities in the province through the five junctions it has. Various state roads are grafted into this network which connect the larger municipalities especially towards the capital municipality and a capillary network of provincial roads which, extending for over 1,500 km, guarantee the local road system.

Slopes characterize the geographical and morphological conformation of the study area; furthermore, a central area characterized by good pedestrian access, with sidewalks in good condition, corresponds to a less well-stocked peripheral area. Overall, the most pedestrianized areas are those crossed by the main road axes, Viale Armando Diaz, oriented in a North-South direction in the western part of the study area, and Via Roma, oriented in a West-East direction, in the eastern part of the area.

The city of Enna has been the seat of the University of Enna Kore for about 18 years and for a few years of a second university called the "Dunarea de Jos" University of Galati. In recent years, this has led to around 8,000 students, around 60% with rent or a home in the context examined. The data used are obtained from ISTAT annals [30], and the implementation was carried out on QGis concerning the study of accessibility [31]. The accessibility range is 5 min, considering an average speed of 1 m/s. The spatial autocorrelation analysis, defined in Chapter 3, was performed on R [32]. With a scale of values from white (zero population) to dark red (460–659 inhabitants), as shown

in Fig. 1, the study area was analysed considering adopting a discretisation approach (ISTAT 2023).

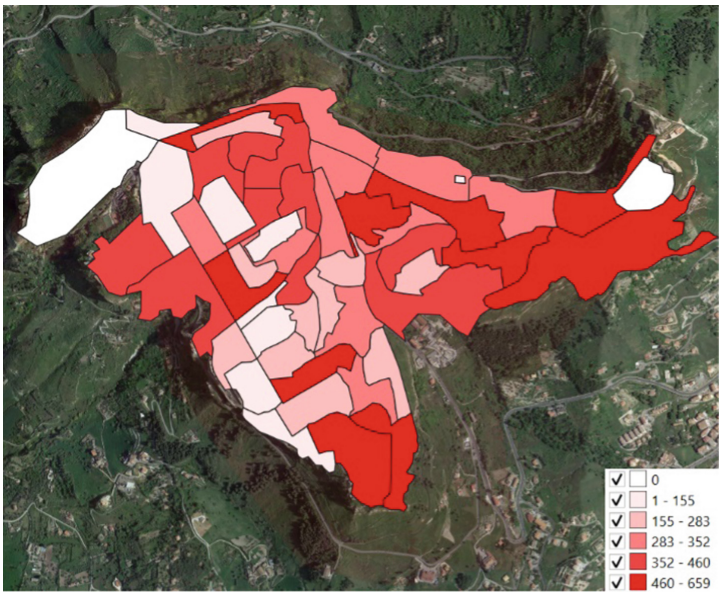

Fig. 1. Case study area and relative residential inhabitant distribution (Source: Authors elaboration by QGis software; background source: Google)

The distribution of students as a percentage of the total population is shown in Fig. 2.with colours from lilac (zero students) to dark purple (more than 12 students).

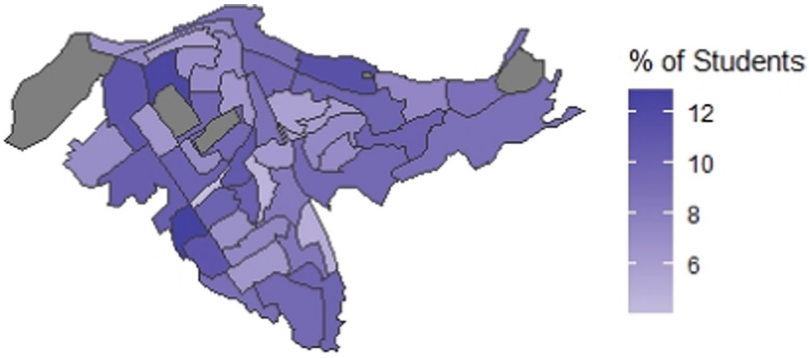

Fig. 2. % of students over total population (Authors' elaboration by R software)

The autocorrelation analysis is carried out by performing the Moran scatter plot analysis and the Moran coefficient study. The results are shown in Fig. 3.

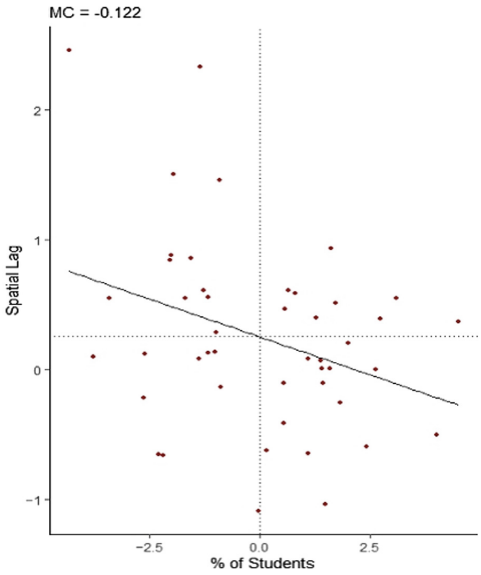

Fig. 3. Moran scatter plot (Authors elaboration by R software)

The analysis shows an absence of patterns in the distribution of students. The calculation of the Moran coefficient returns a value of MC $= -0.122$, which indicates a slight negative spatial autocorrelation.

This makes it possible to state that there are no clusters of areas particularly populated by students, which maintain a homogeneous distribution in the area; rather, it occurs that each area with higher than average percentages of students is surrounded by areas in which the value is the same or slightly lower; similarly, areas with low percentages of students border on areas in which the value is higher than average or about the same.

This does not allow clusters of zones to be identified, and for separating the area into parts more or less populated by students, it is sufficient to characterise them by observing only the values for each zone. From the distribution analysis, the areas characterised by higher student density are mainly located in the western part of the study area, without showing a clear spatial pattern.

4.3 Accessibility of Public Transportation System

The local public transport service is divided into five lines. Of these five, the first is entirely within the study area. Lines 2, 3, 4 and 5 represent the focus of the research under examination, since they concern the connections of the urban area of Enna Alta with the outside world. In particular:

- Line 2 denominated Valverde – Ospedale that, connects the eastern part of the city with Enna bass and in particular with the Hospital
- Line 3 denominated Spirito Santo - Ferrante connects the south-west part of the city with the area where some university faculties are located

– Line 4 denominated Parcheggio Pisciotto - Piazza Garibaldi, which connects a car park near the historic centre with the centre itself
– Line 5 called Terminal Enna Alta - Pergusa connects the terminal bus located in Enna Alta with the village of Pergusa.

Of these lines, the third line connects the centre with the Pisciotto car park. It therefore does not reach the university area; however, the study is carried out, as this line can be used to access the car and therefore has a multimodal function. A substantial part of the stops are located near the road axes referred to in paragraph 4.2; the good pedestrianization of these areas makes it easier to reach the bus stops; sidewalks less cover peripheral areas. Overall, therefore, we have $L = 4$ lines and $N = 51$ zones. The variable P_n used to measure demand is the student population residing within zone n. The results expressed in terms of student population per line are shown in Table 1

Table 1. Bus lane and % of polution P_l distribution

ID bus line	From - To	P_l
1-route 2	Valverde - Ospedale	40,02%
2-route 3	Spirito Santo - Ferrante	64,01%
3 route 4	Parcheggio Pisciotto - Piazza Garibaldi	37,15%
4 route 5	Enna Alta - Pergusa	31,89%

As can be seen, only Line $l = 2$ covers more than 50% of the student population. This is due, in large part, to the fact that it is the line located in the Central-Western part of the city, the one with the highest average density. Lines $l = 1$ and $l = 3$ share an important part of the route, both being located in the Central-Eastern part of the study area. Line $l = 4$ has the fewest stops within the urban area and covers the smallest part of the population.

Of the identified lines, only line $l = 2$ and partly line $l = 4$ cover the western area, which is the most populated. Only line $l = 2$ covers the South-West part of the study area. Figure 4 shows the example for evaluating the isochronous $l = 4$, the Enna Alta-Pergusa line. The main local public transport stops are shown in red, served by bus routes 5.

The LPT connection system is finally evaluated by considering the union of the 4 isochrones considered. The result is shown in Fig. 5.

As can be seen, only part of the settlement in the central and eastern areas are excluded from the overall isochrony. In terms of student population, the overall PTOT value is PTOT = 84%.

5 Discussion and Conclusion

The dislocation of university campuses generates many commuters who need services, including sleeping and living facilities. Depending on the expansion of the cities, some campuses originated in the historic centers. However, most Italian cities have foreseen

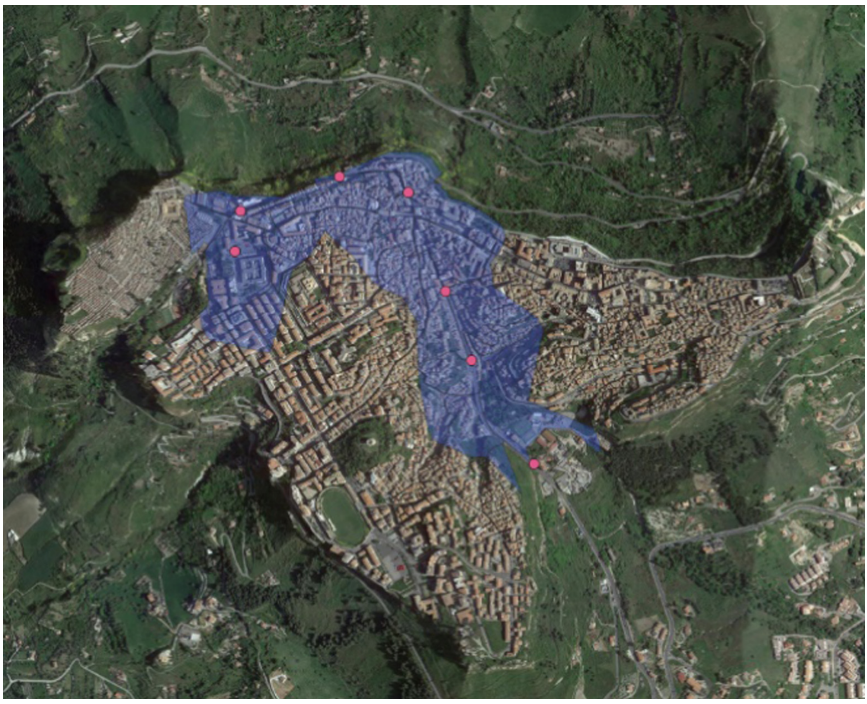

Fig. 4. Isochrone Enna Alta-Pergusa (l = 4) (Source: Authors elaboration by QGis software; background source: Google)

the location of university campuses in peripheral or expansion areas. The development of university cities must be properly planned to ensure that cities with historic centers are easily accessible and inhabited by university students if the campuses are inserted in expansion areas.

The present research work has set itself the objective of analyzing the geographical distribution of the student population in the part of the historic center of the examined area, verifying whether the current LPT system allows good accessibility in terms of territorial coverage for the identified class. Starting from these concepts and considering the dislocation of the census units, the distribution of students was observed in the examined context, which is non-homogeneous.

Considering the case study, it can be observed that the western area has a greater student population than the eastern area of the historical center. Considering the local public transport offer, the distribution of 5 different LPT lines was considered, which allow the connection of the historic center with the other main areas of the city where offices, hospitals and university facilities are located.

The results show an uneven coverage of the areas starting from the study of the isochrones. It should be noted that although lines l = 1,2,4 connect Enna Alta with Enna Bassa, only line l = 1 connects Enna Alta – Est with Enna Bassa, covering 40% of the student population. Line l = 2 reaches most of the population (more than 60%) and covers the entire western area. The l = 4 line only covers the central and northwest area,



Fig. 5. Isochrone union 5 min i_{TOT} per le linee l = 1,2,3,4.

for just over 30% of the student population. More than 80% of the student population is located less than 5 min from a local public transport stop which refers to one of the lines connecting with Enna Bassa.

The results obtained from the double level of analysis on a QGIS basis and the calculation of the isochrones allow us to underline that in the examined area there are no districts which, on a large scale, have characteristics of "student districts". Therefore, it is underlined that the area of the historic center remains inhabited by residents.

Furthermore, it should be noted that the Enna Alta area is covered by accessibility in 5 min, with more than 80%. However, this coverage and, therefore, this estimate of accessibility to urban public transport is spread unevenly among the various lines, with some areas covered by several lines and others covered by a single line.

This result should push the transport service manager in synergy with the local administration to have to implement some services to improve and make the modal choice of urban bus transport more usable and, at the same time, have to implement a series of strategies that can encourage the use of this modal choice, for example by applying discounts, preferential fares or by defining lanes dedicated to public transport.

This research work is the first step in evaluating the accessibility of public transport by the university students of the examined area. In order to improve the accessibility of the historic center, a survey is also planned on other target users, such as older adults. An application of a methodology for assessing accessibility to public transport was shown. The limitation of the research, which will be explored in subsequent works, is limited

to the study of a single mode of transport, the bus. The research will need to expand to include other modes of public transport, particularly in light of developments in more recent forms of shared mobility, such as car sharing.

The next developments include the analysis of the service frequencies, the assessment of the propensity of university students to other sustainable modes of transport (e.g. car sharing) and the study of other characteristics of accessibility (e.g. Walkability).

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