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Investigating the Correlation between Transportation Social Need and Accessibility: the Case of Catania

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Abstract

The development of cities and transportation systems of the last few years made possible to expand the range of individuals, giving them the opportunity to locate their residence far away from the places where they carry out daily activities. The ability to make long journeys has become more and more an essential condition to access opportunities of the territory. This necessity can be connected to transportation social need, which scholars define both in terms of people requiring a public transportation service and number of trips they would make if they had minimal limitations on their mobility; accessibility refers to the ease of reaching goods, services, activities and destinations, which together are called opportunities. This research presents the application of a measure of transportation social need and accessibility for the city of Catania, in Italy. The measure of transportation social need, based on transportation and social disadvantage indicators, has been carried out with reference to Italian national statistical institute zonation of the city. A zonal accessibility measure, considering both private and public transportation and evaluating the ease of reaching desired destinations, have been calculated and an analysis of correlation among transportation social need measure and accessibility measures has been carried out in order to verify the strength of relation between them. Due to the high resolution level of the spatial analysis, manipulation of data and computation of indicators and measures was supported by a GIS approach. Three different public transport scenarios have been analyzed by performing a relative accessibility loss computation showing that improvements in public transport service lead to general improvements in relative accessibility loss.

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Keywords: Transportation Planning; Social Exclusion; Accessibility

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1. Introduction

Social exclusion is a phenomenon influenced by different condition related to quality of life, demographic issues, socio-economic aspects and location of activities and housing. In the last years a new interest in the issue of social exclusion and how it's related to transport disadvantage has grown, and several studies have shown the interrelationship between poverty, transport disadvantage, access to activities and services, and transport related social exclusion (Lucas et al., 2001; Kenyon, 2003; Kenyon et al., 2003; Lucas, 2004; Currie et al., 2007). The possibility to have a good access, in a spatial sense of the term, to work places, education and healthcare services is in fact a key factor to achieve that the whole population could take part to the society (Ignaccolo et al., 2016). Public transport may be able to reduce the mobility gap experienced by several people to reach opportunities and services: physical (availability and accessibility of transport) and economic (cost of transport) barriers or urban structure mobility constraints as in the case of services located in places which are difficult to access; therefore, public transport is a key factor for the improvement of social inclusion. When public transport is poor a Transportation Social Need grows, which can be defined as the number of people in a given geographic area who are likely to require a public transportation service (Rofè et al., 2015). This need is strictly related to the concept of transport disadvantage (Lucas, 2004), which includes a set of individual characteristics related to: location analysis, such as travel time, cost and distance to key life opportunities such as employment, medical centers, shops, education centers and social networks. (Schonfelder and Axhausen, 2003; Dodson et al., 2006); physical and social characteristics of the user that could limit personal access, such as in the case of the elderly (Rosenbloom and Morris, 1998), unemployed youth (Currie et al., 2007), people with low-income, or with cultural and language barriers (Litman, 2010); transport opportunities access such as accessibility.

Due to all of these reason, the analysis of public transport disadvantage and social needs together with transport provision, and in particular access opportunities offered by the system, are essential in order to see where the system can be improved (Lucas, 2004; Currie et al., 2009) and to guarantee vertical equity among population.

This research is focused on the analysis of accessibility measures as tools to address the equity dimension of transportation through an application for the public transport services in the city of Catania, in Italy. This issue has been explored since a lack of accessibility has a serious impact on people's life and may prevent them from finding a good job, have a good education, reaching health care services, as well as having enough social contacts (Lucas 2012). The objective of the study is to analyze the connection between people's social condition and accessibility to opportunities and services by public transport, with particular reference to the case of the city of Catania.

2. Methodology

2.1. Measuring transport need

The interest in the concept of a transport disadvantaged population has grown from the fact that traditional transportation planning methods usually aim to satisfy travel demand and do not take into consideration social-economic aspects (Hine and Mitchell, 2001). Actually, transport and social disadvantages interact to cause what can be called "transportation poverty" that leads to inaccessibility to essential activities and thus to social exclusion. Therefore, both a social disadvantage index (based on income, employment status, skills level, health problems, poor housing) and transport disadvantage indices (based on accessibility, car ownership, poor public transport services, high cost of fares, no information, fear of crime, etc.) should be taken in account together (Currie, 2010, Lucas, 2004).

In order to introduce a measure of transport disadvantage, Currie (2004, 2009, 2010) proposed an aggregate indicator based on social needs, called Transport Need Index (TNI), based on socio demographic data. The index consists of weighted indicators of social and transport needs that combines together characteristics of income, employment status, car ownership and health (Currie, 2009; Currie, 2010). The weights are derived from the degree of low trip making (Currie, 2007). Each indicator is normalized to values between 0 and 100. The final need index is a sum of the weighted normalized values. The structure of the index proposed by Currie was first used in some Australian cities and later applied in the city of Palermo in Italy (Amoroso et al., 2010) and Santiago de Cali, Colombia (Jaramillo, 2012) as well, with modified weighs more in accordance with its different socio-economic conditions.

For the evaluation of a measure of Transportation Social Needs in our study, the method proposed by Currie was taken as a baseline and modified to match the available data and socioeconomic conditions relevant to the city of Catania. The index itself is a weighted sum of the following transport and social disadvantage indicators within the area of analysis: people aged over 15 with no income, people aged over 65, members of families with 6 members or more, unemployed people (people aged over 15 without a job), students, and people aged 0-15. These statistics are taken from Italian Statistic Institute (ISTAT) database for each census tract. A score for each need indicator is identified by normalization of each value; normalization is based on the relationship between the score and highest value of the indicator. In this first application of the methodology, the weights were assumed to be equal for each of the indicators used. but, obviously, this aspect should be better addressed in future research developments.

Table 1 Transportation Social Need indicators and weights.

Need indicator	Description
SI_1	People with no income (ISTAT, 2011)
SI_2	People aged over 65 (ISTAT, 2011)
SI_3	Family members with 6 members or more (ISTAT, 2011)
SI_4	People over 15 without a job (ISTAT, 2011)
SI_5	Students (ISTAT, 2011)
SI_6	People 0-15 (ISTAT, 2011)

The overall index (TNI) is calculated as the sum of the Standardized Indicators (SI) for all chosen six factors within each zone, as showed in Equation 1. As a result, the more disadvantaged the area, the higher is the index.

$$TNI_i = SI_{1i} + SI_{2i} + SI_{3i} + SI_{4i} + SI_{5i} + SI_{6i} \qquad (1)$$

2.2. Measuring accessibility

Accessibility can be defined as the ability of people to access necessary or desired activities by different transportation modes (K.T. Geurs, J.T. Ritsema van Eck, 2001). It is considered a key criterion to assess the quality of transport policy (Kenyon et al., 2002) and one of the main reasons for to the urbanization of metropolitan areas (Handy and Niemeier, 1997). At the same time, accessibility indicators can measure social issues when they incorporate the level of difficulty experimented by different social categories of individuals to reach the economic opportunities or social activities throughout the area.

The literature distinguishes two forms of accessibility (Pirie, 1979; Kwan, 1999; Miller, 2007; Cascetta, 2009):

- Active accessibility (or person-based accessibility) refers to the need to carry out the activities located throughout the area by a user that is in a particular place (generally the resident) and it measures the ease with which he can reach various destinations from an origin. It is useful in locating settlement decisions.
- Passive accessibility (or place-based accessibility) refers to the need for the various opportunities that are located in a certain area of the territory, to be reached by the various users scattered throughout the study area. In other words, it measures the ease with which business and services of a target area of the displacements can be reached by the users concerned. It is useful in the location decisions of public services and economic activities.

Most of the literature refer to activity-based accessibility formulations, whose indicator is a function of the amount of spatial opportunities that is possible to reach and the relevant generalized transport cost. In particular, the accessibility indices based on gravitational models provide a continuous measure, where the value of the opportunities is weighted by a spatial impedance function. The impedance function reflects the effect of decreasing accessibility due to the increase of distance, travel time, or in general of the generalized cost of transport.

The first application of the gravity model to accessibility measures is attributed to Hansen (1959), which suggested that accessibility across regions was directly proportional to the attractiveness factors (jobs, shops, sports centres, etc.) and inversely proportional to the travel time between the zones, which represents the cost of moving. The

Hansen's index has the following form:

$$A_i = \sum_{j}^{n} O_j \cdot f(C_{ij}) \tag{2}$$

Where O_j is the number of opportunities in the zone *j* and $f(C_{ij})$ the impedance function among zones *i* and *j*. A negative exponential impedance is often used, such as:

$$f(C_{ij}) = e^{-\beta \cdot C_{ij}} \tag{3}$$

With C_{ij} generalized cost of travel among *i* and *j* zone and β is a parameter related to the cost, that can be estimated by a gravity model.

This type of indicator offers the advantage of requiring a relatively small amount of data (ease of processing and calculation), allowing to differentiate the areas of study and to derive the accessibility indices for each of them. They are particularly useful for assessing the potential of suburban residential areas in allowing access to activities such as shops, schools, workplaces, health care and other services.

2.3. Relative accessibility loss

From an equity perspective, a comparison between accessibility for different transport modes is required (Martens, 2009; Ignaccolo, 2016). Then in this study a Relative Accessibility loss due to the reliance on public transport for travel to work will be calculated with reference to the need index of each zone which reflects the ratio of public transport dependent population to the overall travelling population, with reference to the method proposed by Rofè (Rofè et al., 2015):

$$R_i = TNI_i \cdot \left(1 - \frac{PA_i}{CA_i}\right) \tag{4}$$

Where PA_i is the Public Transport Accessibility evaluated through the Hansen Index considering as impedance a function based on the generalized cost of transport and taking into account parameters such as travel time, the cost of travel time, the number of transfers and considering a flat travel fare; CA_i is Private Car Accessibility, considering as impedance a function based on the travel time in unloaded network. Regions can be ranked by their Relative Accessibility loss. If R = 0 (i.e. no loss), there is no Transportation Social Need, or bus and car service access to areas are equal. If the need is high, or the public transport accessibility index is low, then R tends to 1. R can be estimated at any spatial level from individual buildings up to the entire metropolitan area.

3. Case Study

3.1. Territorial Framework

Catania is a city of about 300,000 inhabitants, located in the eastern part of Sicily (Southern Italy); it has an area of about 183 km2 and a population density of 1,754.54 inhabitants / km2. It is part of a greater Metropolitan Area (750.000 inhabitants), which includes the main municipality and 26 surrounding urban centers, some of which constitute a whole urban fabric with Catania. The main city contains most of the working activities, mixed with residential areas. With reference to the urban area, the transport service is provided by 51 bus lines, a shuttle line (ALIBUS) connecting the city center to the airport and a second express bus (called Bus Rapid Transit - BRT1) connecting a park-and-ride facility on the northern periphery to the city center. BRT1 is the first of three lines provided by the City of Catania with equipped lanes protected by curbs on the majority of their path and was commercially promoted as Bus Rapid Transit. In Catania it is also present an urban subway line that currently connects the city center with the north west zones of the city.

3.2. Data collection and transport model

Both TNI and accessibility measures requires demographic and socio economic data, provided by the most recent ISTAT database dating back 2011. For the calculation of the impedance measure included in the accessibility, a mathematical model of the transport system has been built within TransCAD, a software which combines a GIS and a set of transport models in one integrated environment. The software evaluates Hansen Index providing standard values for deterrence index β, based on the selected transport mode and type of opportunities at destination and parameters for the gravity model (Ignaccolo et al., 2016). In this study job places will be taken into account as opportunities to be reached from each zone. The zonation used for the city is the one given by ISTAT, which divides the study area in 2,480 census zones. Three different scenarios have been analyzed. The first one, called Scenario 0 (Fig. 1a), includes 51 bus lines with an average operating speed of 15 km/h; the second one, called Scenario 1, provides for the introduction of three BRT lines and the subway line (Fig. 1b);the last one called Scenario 2, provides for a general increase of all bus lines operating speed from 15 km/h to 18 km/h (conventional bus lines).

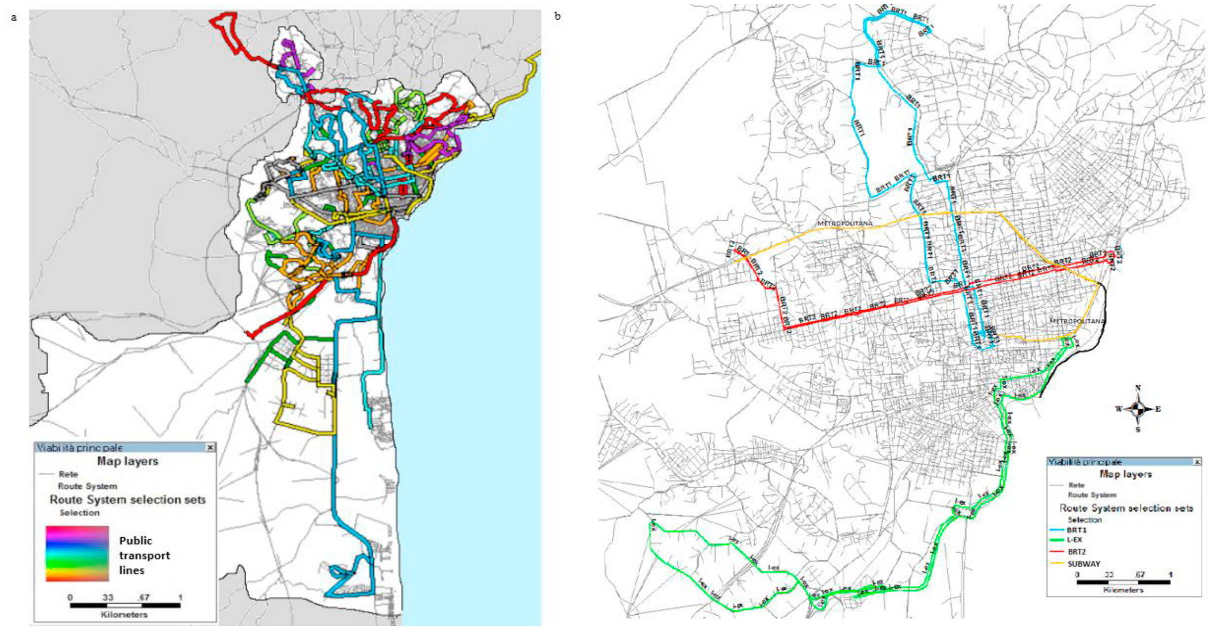

Fig. 1. (a) Scenario 0, (b) Improvements in the transport system of Scenario 1

All indicators of transport disadvantage indicated in *Table 1* are normalized with values between 0 and 1 and were calculated for each zone; the results are presented using the Jenks Natural Breaks data classification system (Jenks, 1967). Maps of indicators have been elaborated by using QGIS software (Fig. 2).

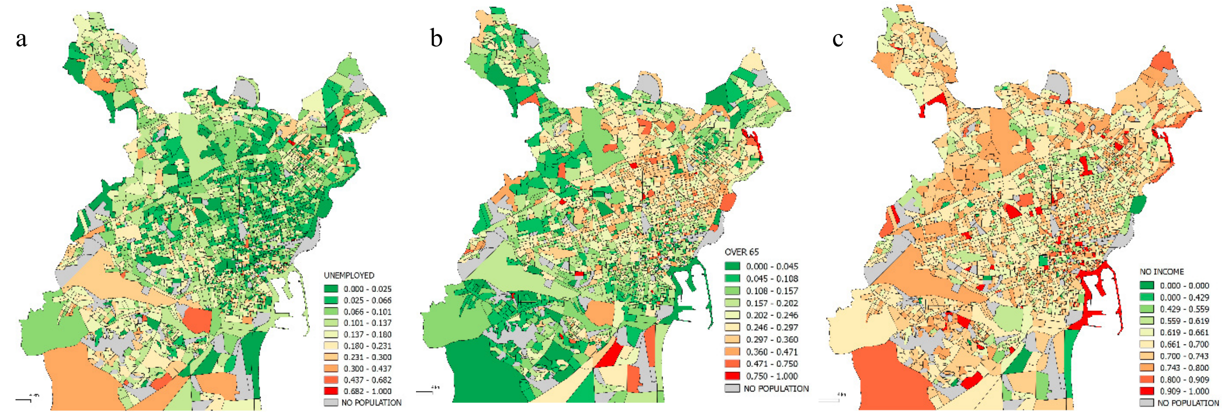

Fig. 2. Map of three of the standardized indicators SI_4 (a), SI_2 (b), SI_1(c)

4. Results

Fig.3a shows the spatial distribution of composite need index for urban area of Catania; from the map it's possible to evaluate that high values of TNI can be found in the city center, in the South-West suburban areas and in some regions in North-West. In Fig.3b the share of values of each need indicator factor for zones with highest value of TNI are shown.

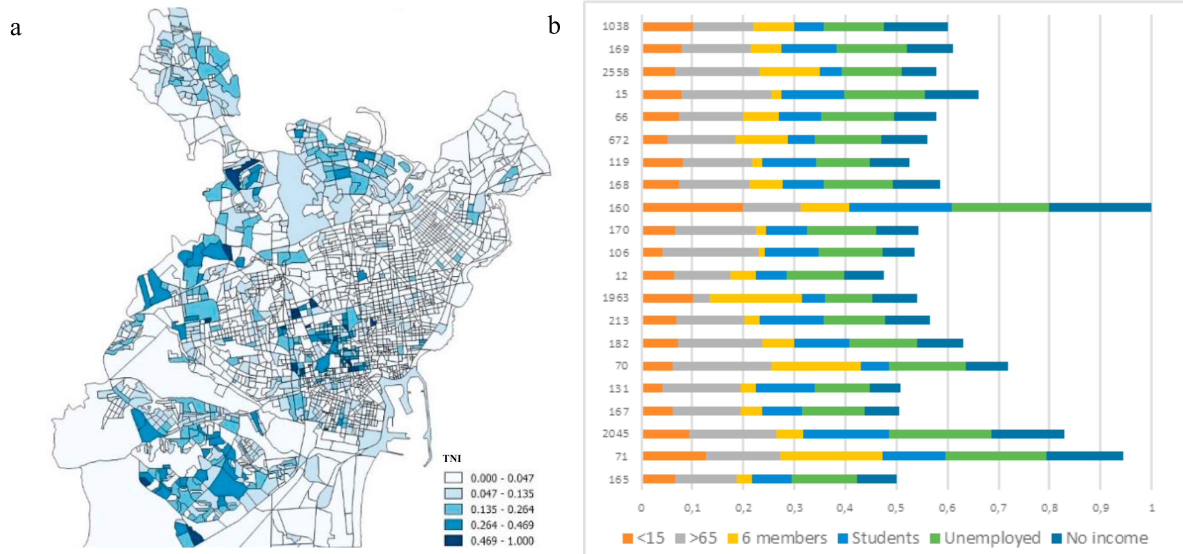

Fig. 3. (a) TNI spatial distribution, (b) share of values of each Transportation Social Need Indicator factor for zones with TNI>0.5

Fig. 4 shows Hansen Index results for accessibility to job places for the Scenario 0 and improvements in Scenario 1 and 2; results show that the introduction of the improvements both in Scenario 1 and Scenario 2 provide an increase of accessibility, with slightly better improvements in Scenario 2.

Fig. 4. (a) Accessibility by public transport for Scenario 0, (b) improvements in Scenario 1, (c) improvements in Scenario 2

To examine further the relationship between the transport system and socio-economic dependence on public transport we look at the scatterplot relating the Transportation Social Need Index and the Hansen Accessibility measure for public transport accessibility to job places for Scenario 0. For the analysis of the correlation both measure have been normalized between 0 and 1. The graph in Fig.5 highlights that most of the zones have a high level of accessibility and low values of need index. Those high levels of accessibility are due to the fact that the public transport service has a high spatial coverage across the territory but the transport model used in this first application of methodology is not sensible to service frequency, so high values of accessibility could not necessarily correspond to high level of performance of the public transport service. In future studies statistical calculation could be used to evaluate the quality of correlation.

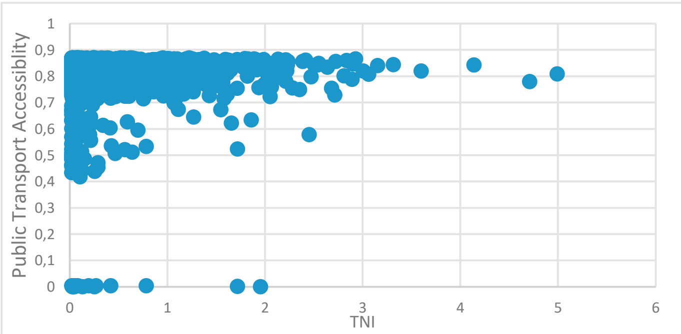

Fig. 5. Scatterplot of Transportation Social Need Index and Accessibility to jobs index from the city of Catania

On the basis of the relative accessibility, and the Transportation Social Need Index, the relative loss of accessibility due to location and dependency were calculated for both Scenario 1 and 2 with reference to the computation of accessibility measure by private transport performed in previous studies (Giuffrida et al., 2017). Fig. 6 shows the difference between the scenarios and where these losses were reduced or became larger. Relative accessibility loss refers to clean areas, quite similar to those of the Transportation Social Need Index map, due to the common values of accessibility indices by public transport throughout the city; both scenarios show an overall improvement, but gap among zones is still present and distribution remains unequal.

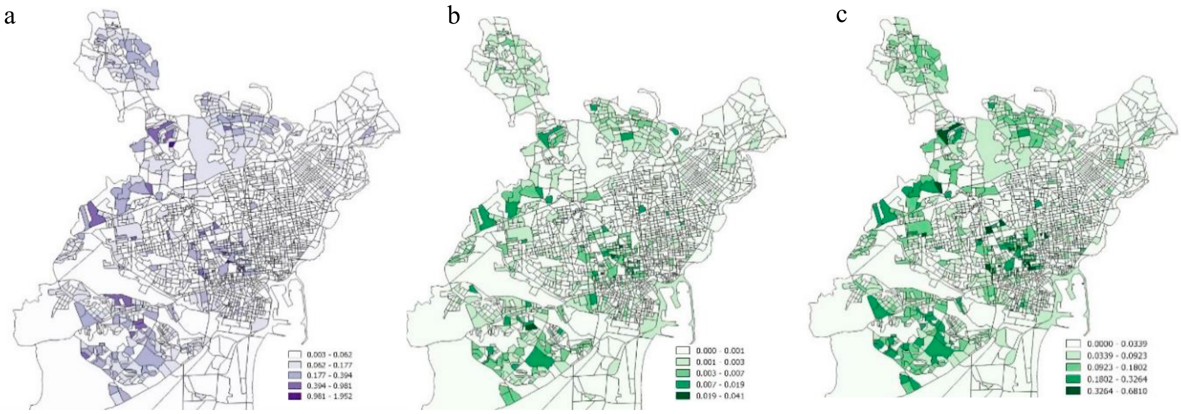

Fig. 6. (a) R for Scenario 0, (b) improvements in Scenario 1 ($R_{S0} – R_{S1}$), (c) improvements in Scenario 2 ($R_{S0} – R_{S2}$),

5. Conclusion

The interest in sustainable development, which has grown in the last few years, has emphasized the importance of public transport accessibility. However, there are still many citizens who have limited or fewer access to public transport than others, and the aim of public policies should be to improve the quality of life of weakest sections of population, in order to reduce social exclusion.

In this paper an application of a measure of Transportation Social Need and measures of accessibility for the city of Catania has been presented, with reference to three different public transport scenarios. Results coming from the analysis of socio economic data showed that there are clean patterns with a high level of Transportation Social Need Index. High spatial coverage of the public transport service lead to a correlation between Transportation Social Need Index and Hansen Accessibility Index that shows that public transport in Catania should offer good access to people even with low Transportation Social Need, but future research should be conducted in order to verify this result. Finally, a relative accessibility loss computation has been performed for three different scenarios and it revealed that improvements in public transport service lead to improvements in relative accessibility loss but still maintaining a certain gap among zones and, consequently, an unequal distribution.

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