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Addressing the public transport ridership/coverage dilemma in small cities: A spatial approach

Nadia Giuffrida[a,*], Michela Le Pira[a], Giuseppe Inturri[b], Matteo Ignaccolo[a]

[a] Department of Civil Engineering and Architecture, University of Catania, via Santa Sofia 64, Catania 95125, Italy
[b] Department of Electrical, Electronic and Computer Engineering, University of Catania, via Santa Sofia 64, Catania 95125, Italy

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ABSTRACT

This paper presents a spatial approach to support the design of new on-demand flexible transport services in urban areas, characterized by inefficient public transport and modal imbalance in favour of private cars. These services, enabled by new technologies and inspired by the shared mobility paradigm, can complement and improve conventional public transport and reduce car use. The methodology was applied to Acireale, a small town in Southern Italy. A redesign of the existing bus network and its integration with a flexible service was formulated. A scenario analysis was carried out by the evaluation of a simple accessibility measure; the computation of the Gini coefficient was performed to measure the social equity of different scenarios. Results show an increase in equity with a lower coverage of traditional lines and the introduction of the on-demand service. This approach based on easy-to-understand indicators can help the strategic planning of such services, which have the potential to find a trade-off between ridership and coverage as both desirable and conflicting goals in public transport planning.

1. Introduction

Planning for sustainable mobility means planning for accessibility (Banister, 2008). The concept of accessibility as “the potential of opportunities for interaction” (Hansen, 1959) has been developed over the years in different ways. In general, it can be considered a good indicator of successful land-use and transport policies, when the goal is reaching a diversity of places by a combination of desired transport modes within a given travel time and/or cost (Ben-Akiva and Lerman, 1979; Bhat et al., 2000; Geurs and van Wee, 2004; Bertolini et al., 2005). Planning to increase the “ease to reach a destination” is often in contrast with planning for “mobility”, which instead can be considered as the “ease to move”. In this respect, transport is generally a derived demand and has not an end in itself. Besides, it has been demonstrated that accessibility is highly correlated with transport energy dependence, meaning that a good accessibility implies less energy for transport (Ignaccolo et al., 2016b; Inturri et al., 2017). This is particularly relevant in the emerging context of electric mobility and the potential role of autonomous energy production systems (Fichera et al., 2016; Volpe et al., 2017).

Therefore, sustainable mobility should be achieved through a fair and widespread accessibility to all categories of transport users (passengers/freight). However, typical problems characterising modern cities, e.g. urban sprawl and limited resources for transport infrastructures and operation, pose important challenges in developing a pervasive accessibility.

In such a bounded context, the risk of social exclusion derived by a scarce transport supply is very high. Social exclusion may arise from many factors related to quality of life, such as demographic issues, socio-economic aspects and location of activities and housing (Giuffrida et al., 2017). Literature on the correlations between poverty, transport disadvantage to access activities and services, and transport related social exclusion is abundant (Lucas et al., 2001; Kenyon et al., 2002; Lucas, 2004; Currie et al., 2007). This problem is further exacerbated in small cities, peripheral and rural areas, and sprawled urban areas (the so called “low-demand areas”), which usually lack of an effective and cost-efficient local public transport service, implying an exclusive use of private vehicles, though restricted to who can afford it.

In this context, innovative transport services based on ICT technologies, enabling the new shared mobility paradigm, may contribute to reduce the risk; in particular, Demand Responsive Shared Transport (DRST) can be regarded as one of the solutions able to respond to changing mobility demands (Attard et al., 2019). The high ownership

* Corresponding author.
E-mail addresses: nadia.giuffrida@dica.unict.it (N. Giuffrida), mlepira@dica.unict.it (M. Le Pira), giuseppe.inturri@unict.it (G. Inturri), matteo.ignaccolo@unict.it (M. Ignaccolo).

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rates (even in the lowest social classes) of smartphones, equipped with fast and efficient algorithms, enables today the potential for a wide range of flexible transit schemes, with intermediate performances between car and transit. These could reposition the concept of public transport and fill the gap left by conventional transit, if one wants to limit car dependency.

Technology-enabled DRST services can be a valuable solution being flexible and operating on routes, stops and timetables that can vary according to requests generated by users. Such services can still be classified as public transport, since the supply is available to anyone who requests it and within the limits of the service's capacity. They are non-scheduled services since routes, stops and timetables are not prefixed but changeable with the users' requests. Flexible transport systems are useful to cover a performance gap between individual transport (private car or taxi) and conventional line transport (buses), especially in low-density urban areas, characterized by irregular demand, and in small urban centres. Following the shared mobility approach, rides (and costs) can be shared by users, thus enhancing the service efficiency and equity by providing a more extended and frequent public transport, flexible mobility schemes and feeder services (Inturri et al., 2019) (see Fig. 1).

DRST services can perform different functions, i.e.: (i) service with origin/destination (OD) dispersed in an extended area (e.g. taxi sharing); (ii) service on a fixed route with deviations (e.g. minibus); (iii) feeder service of fixed route transit terminals; (iv) service for particular categories of users (e.g. disabled people).

New technologies play a fundamental role in allowing the development of new transport services with flexibility and intermediate performance in terms of cost, sustainability, and vehicle occupancy. They allow to locate users and vehicles in the network, assign the most suitable vehicle to serve one or more users with travel needs similar to those already scheduled and compatible with the vehicles' residual capacity, select the most suitable route to accomplish the requested service, and perform an electronic payment of the service. In this respect, different studies reproduced DRST services via simulation models, such as agent-based models (ABM), showing how this service can be suitable to satisfy different ranges of weak-demand, also compared to similar services (Inturri et al., 2019).

A further aspect is that web-based technologies enhance the recording and collection of large amount of data, e.g. OD data, number of users boarding/alighting at the different stops, vehicle coverage, cancellations, no-shows, punctuality, and speed. These data can be used both at the tactical operation level by a dynamic modification of the service schedule, and at the strategic planning level to change the design of the service. The design of such services can address a significant reduction of social exclusion by improving accessibility.

In this respect, a sound spatial analysis could provide a valuable planning support tool to address what can be called the "ridership/coverage dilemma". Ridership is a consequence of the efficiency of the transport service; it increases if the service reaches as many users as possible. While this is easy to perform in very dense central urban areas, a good coverage is difficult to achieve, especially in small and dispersed areas, if one wants to maintain an acceptable efficiency of the service (in terms of time and cost). A compromise is needed to solve the dilemma, particularly in the context of limited financial resources. Strategic planning needs clear and easy indicators to understand the potential of investments. Based on this premise, this paper will present a methodology based on a spatial analysis, which relies on accessibility measures as the first step to design DRST services in small urban areas characterized by inefficient public transport and modal imbalance in favour of private transport. Besides, it allows to understand the contribution of these new services to social inclusion. The methodology has been applied to Acireale, a small touristic city in Southern Italy. In a context characterized by scarce resources, a redesign of existing public transport bus lines together with a proposal of complementary flexible services was formulated. The analysis of the new scenario will be carried out by accessibility evaluation via a simplified method inspired by the Public Transport Access Level (PTAL) (TFL, 2008) taking into account only indicators related to public transport. Next section will present a succinct literature review on methods that can be used to help the design of public transport and address the ridership/coverage dilemma, and will define the novelty of this study.

2. Literature review

Literature on methods to support the design of public transport network and routes is quite vast (Ceder and Wilson, 1986; Ceder, 2002). Kepaptsoglou and Karlaftis, 2009 report a review of studies related to the so called transit route network design problem, recognizing that it is inherently a multiobjective problem, involving trade-offs and different objectives, both from the user and operator perspectives, such as travel and waiting times for the user, and capacity and operating costs for the operator.

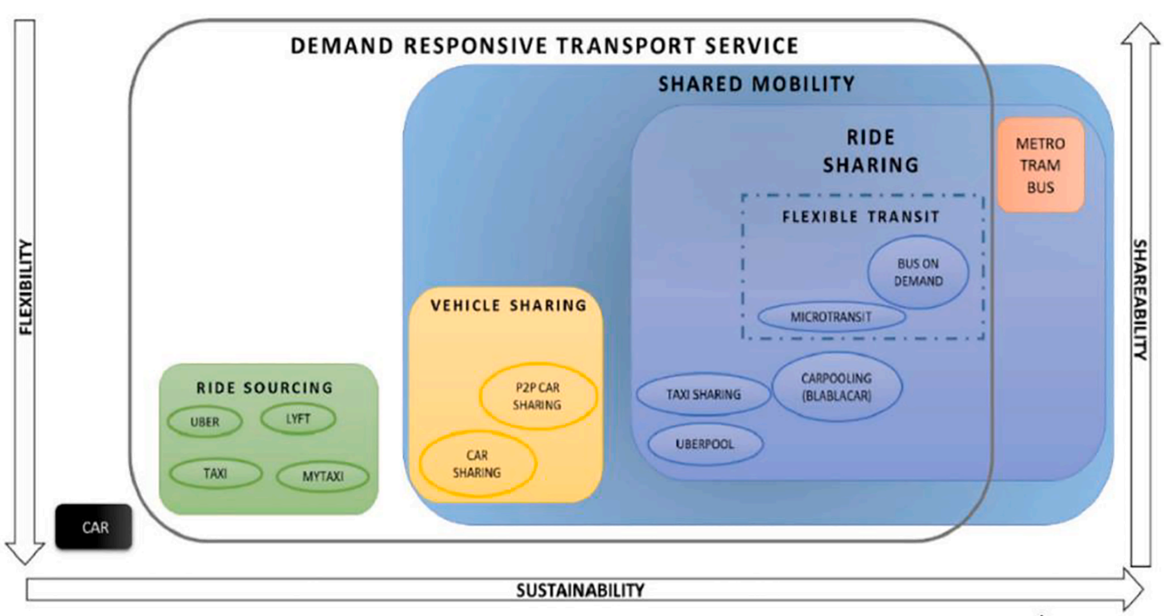

Fig. 1. The flexibility-sustainability-shareability-cost graph of motorized transport services (Inturri et al., 2019).

In general, optimization models are used for transit network design, including optimal transfer, route directness, and ridership (Guihaire and Hao, 2008; Zhao and Ubaka, 2004). Bielli et al. (2002) defined a heuristic based on genetic algorithms for improving the performance of existing networks, by reducing the number of vehicles, without penalizing the average travelling time. In this respect, heuristic algorithms have been found to be useful to solve different transport problems, e.g. the travelling saleman problem (Roy et al., 2019), multi-depot vehicle routing (Barma et al, 2019), or feeder bus network design (Calabrò et al., 2020), just to cite few examples.

Zhao and Ubaka (2004) proposed a computational tool for the optimization of large-scale transit route networks, by minimizing transfers and optimizing route directness, while maximizing service coverage. They performed tests and applied the tool to a large-scale realistic network optimization problem in Miami-Dade County, Florida. Pagès et al. (2006) proposed a three-level hierarchical optimization approach to solve the mass transport network design problem, which is typical of flexible large-scale mass transportation options that use new technologies for communication among passengers and vehicles.

Murray et al. (1998) discussed access and accessibility, which are both important elements of service provision. Access typically has to do with proximity to service and its cost, whereas accessibility relates to “the suitability of the transit system to move people from where they board to where they exit in a reasonable amount of time”.

In this direction, Murray (2003) developed a hybrid coverage model for simultaneously expanding service access and increasing accessibility for public transit service in Brisbane, Australia. The author argues that an operational level concern in transit planning focuses on the spatial efficiency of service coverage, and that bus-oriented transit management and planning must address both expanding service coverage and increased efficiency of routes.

Mattson (2017) estimated ridership models for rural demand–responsive transit for the general public, using a vast set of variables and deriving some useful information for correct planning of demand-response transit services in rural areas. In this respect, the author found out that the ridership would be lower if the agency also operates a fixed-route service or if its service area overlaps that of another transit agency, while the possibility of reservation on shorter notice implies higher levels of ridership.

Notwithstanding the usefulness of these models, they usually fail to address the coverage/ridership problem in a simple and understandable way for policy-makers that should plan the service. Walker (2008) deals with the need of quantifying the tradeoff between coverage and ridership and how to facilitate public discussion and decisions on how to balance these priorities. This becomes even more important considering the involvement of non-experts in participatory transport planning processes (Le Pira et al., 2015, 2016; Gonzalez-Urango et al., 2020). In this respect, an integration of Public Participation, GIS and quantitative evaluation methods, in particular Multi Criteria Decision Analysis, proves to be beneficial to foster technically sound and shared decisions (Giuffrida et al., 2019). Besides, while recent models have been used to help the planning and designing of new DRST services (see, e.g. Inturri et al., 2018, 2019; Giuffrida et al., 2020), there is a lack of spatial analysis and methods able to integrate conventional scheduled public transport with on-demand flexible services. This is the main novelty of the study, which can be considered as a first step towards the planning of integrated fixed and flexible transit services, based on accessibility and social equity indicators. It is worthy of notice that, even if accessibility and equity are not able to encompass all the fundamental design and operational characteristics of public transport services (e.g. travel and waiting times, capacity, operating costs, route directness), they should be interpreted as the final goals of an efficient and effective public transport aimed at sustainability (Inturri et al., 2017).

Next sections will show the methodology and its application in a case study.

3. Methods

This study aims at evaluating the integration of new on demand mobility services enabled by technologies and inspired by the shared mobility approach with conventional public transit. The methodology is based on three main steps, i.e.:

- Analysis of the current Access Index (AI) of a given area served by a conventional public transit network.
- Development of a new transport solution combining conventional public transit with DRST services, with attributes derived from spatial considerations and analysis of the new AI.
- Scenario evaluation in terms of social inclusion by comparing the related Lorenz Curve and Gini Index.

Fig. 2 reports the rationale behind the proposed procedure. It can be seen as a cyclical process based on a repeated evaluation of accessibility. It could be used whenever a transit network re-design based on rationalization is needed with the inclusion of flexible services, allowing to understand the impact of the new configuration on social inclusion.

Each step is explained in the following.

3.1. Analysis of current access index

The calculation of accessibility to the service was conducted with a simplified method inspired by the PTAL index, originally developed by Transport for London, as an indicator to rank locations by distance from frequent public transport services. The calculation procedure can be broken down into the following steps:

- Calculation of Walking Time (WT) to access the Service Access Point (SAP), i.e. the station or stops of the transport service, by walking at the average speed of 4,9 km/h. The radius within which to consider the various SAPs varies according to the mode of transport; it is assumed that each user will walk for a maximum of 640 m (8 min) in the case of bus service.
- Calculation of Scheduled Waiting Time (SWT) at the stop, as half of the headway (time interval between two transit runs). Headway is the inverse of transit frequency (veh/h) and therefore SWT = 0,5 * (60/frequency), if waiting time is expressed in minutes. The frequency is calculated considering the hourly interval from 8:00 to

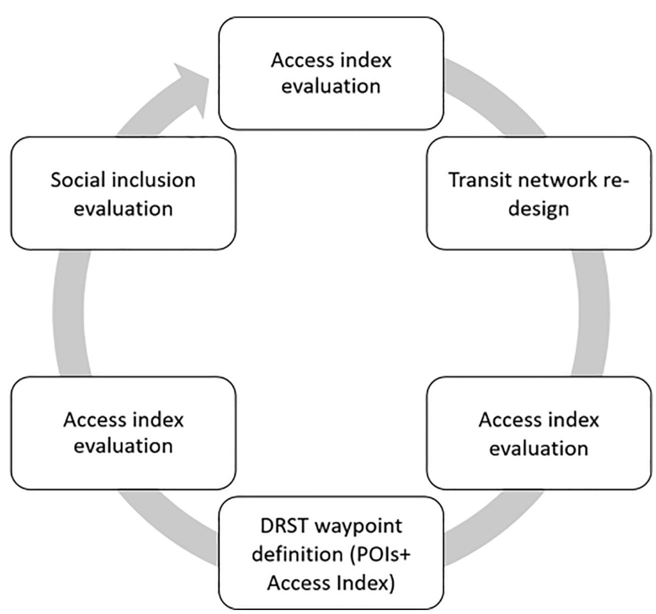

Fig. 2. Flowchart of the methodology.

9:00, since it represents the peak hour service. If there is more than one stop of the same line in a given area, we consider the nearest one, while if the service works in both directions at the same stop, we consider the one with a higher frequency.

- Calculation of the Average Waiting Time (AWT). The waiting time at a stop may be subject to variations, mainly due to service delays. Therefore, the waiting time is corrected through the reliability factors, which vary according to the transport mode (2 min in the case of buses).
- Calculation of Total Access Time (TAT), as the sum of the contribution coming from the WT to access the SAP and from the AWT. Then TAT = WT + AWT.
- Calculation of the Equivalent Doorstep Frequency (EDF). It is a measure of what the frequency would be if the service was available without considering any walking time, or rather representing an equivalent frequency. It is calculated with the equation EDF = 0,5 * (60/TAT), i.e. by dividing 30 min by the TAT, as a proxy to convert TAT to an AWT, as the routes were available at the doorstep of the POI.
- AI calculation. The procedure assumes that the user chooses the most convenient stop within each cell on the basis of a higher EDF value; this assumption is respected by assigning a greater weight to the stop which has a higher EDF value and a lower weight to the rest. Then the specific access index is calculated for the single mode of transport given by the sum of the EDF with the greater value multiplied by 1, and by the remaining EDF multiplied by a value equal to 0,5. In the same way, the access indexes relative to the other modes of transport are calculated. The total AI is calculated as the sum of the indexes of each mode; e.g. in our study, since only bus mode is available, AI will be calculated as follows: $\text{AItot} = \text{AI}_{\text{bus}} = \text{EDF}_{\text{bus}}$.

The original PTAL method has, as final step, the conversion of the AI to a PTAL ranking, with a score from 1 to 6; in this paper, also due to the simplification of taking into consideration only urban public transport, the resulting AIs values would not make it possible to appreciate the differentiation among the different PTAL grades. It was therefore decided to calculate the AI for each cell and to take the normalized values as the reference for the mapping procedure, without providing a classification of the scores. The use of the normalized value allows to evaluate a relative increase in accessibility compared to the actual situation and therefore to perform a correct comparison of different public transport scenarios.

3.2. Development of a new transport solution from spatial considerations

In a context characterized by scarce resources, a redesign of existing public transport lines together with a proposal of complementary flexible services could be a solution to increase its efficiency.

The proposed solution relies on the constraint that the urban public transport network will be reorganized, while maintaining the available resources unchanged (number of vehicles and drivers); keeping this in mind, a scenario was designed using all available resources to largely increase the frequency of a single transport line that connects the railway station to the city centre along a high demand corridor due to the large number of activities. On the basis of these premises, it was decided to propose the introduction of an on-demand service in the areas no more covered by the conventional public transport lines. The rational of the on demand service is that, if on one hand it could have a lower cost than a traditional line (given the use of smaller vehicles), on the other hand it might guarantee a better reliability in terms of waiting times for users who request it (precisely because it is “on-demand”) and better efficiency through higher load factors. Furthermore, these on-demand services are increasingly becoming the prerogative of private companies; consequently, the possibility of a Public Private Partnership (PPP) could reduce (or even eliminate) the need for a public contribution and allow a reorganization of the urban service of such type with unchanged resources.

This rationalization of the transit network reduces the number and length of the transit lines (less spatial coverage) and increases the frequency and regularity of the service on a few remaining lines. These are redesigned to favour the access to the principal service and points of interest (POI) of the territory, or directly or through the connection with complementary on-demand services. They can be operated with smaller vehicles (e.g. minibuses, vans) running along demand-responsive flexible routes and pre-fixed locations of stops; such locations, here defined as *waypoints*, can be chosen through a spatial analysis of the lack of coverage of the main POI of the territory following the new organization of the traditional bus lines. Following the shaping of the new public transport layout and organization, a new evaluation of the AI is performed: on-demand stops can be introduced in the calculation, with a given headway, e.g. 10 min, which can be considered as the maximum waiting time value for a user of such flexible services based on the result of several studies already conducted by the authors related to the planning and simulation of on-demand mobility services (see e.g. Inturri et al., 2018, 2019).

3.3. Comparison of Lorenz curve and Gini index for scenarios

Assuming the existence of a correlation between accessibility and social inclusion, the assessment of the social equity and its variation can be verified through the tracing of the Lorenz curve and the calculation of Gini coefficient (Ignaccolo et al., 2016a). The Lorenz curve was created as an aggregate measure of the distribution of wealth within a population and it is generally used in the economic field for the analysis of inequality of income distribution. In the transport field, the use of the Lorenz curve represents a simple and effective graphical representation of horizontal inequality, by providing a measure of the overall accessibility compared to the entire population (Delbosc and Currie, 2011). The horizontal axis of its graph shows the cumulative percentage of the population under examination (from 0 to 100%), sorted according with increasing values of accessibility, while the vertical axis measures the relative cumulative percentage of the indicator itself. Each point of the curve indicates the percentage of accessibility globally owned by a given percentage of population. The ideal of equal distribution is represented by a line at 45°: the more the Lorenz curve deviates from the equal distribution line, the higher is the inequality of the distribution of accessibility through population.

The relationship between the area embraced by the Lorenz curve and the straight line of equal distribution and the area below the line of perfect equality is the Gini coefficient, a mathematical measure of the degree of inequality introduced in 1912 by the Italian statistician Corrado Gini, which can be mathematically calculated using the following approximate formula:

$$G = 1 - \sum_{k=1}^{n} (X_k - X_{k-1}) \cdot (Y_k - Y_{k-1})$$

where *Xk* is the generic interval of the cumulative percentage of the population variable and *Yk* is the corresponding interval of accessibility cumulative percentage, for $k = 1, \ldots, n$ number of zones and $Y0 = 0$, $Yn = 1$. Gini coefficient can take any value between 0 and 1. A value of 0 corresponds to a situation of equality, while a value of 1 to complete inequality: the lower the coefficient, the lower the inequality of the distribution concerned. This method can be used to analyse changes in distribution of accessibility (and accordingly of equity) over time and also to compare social exclusion in different regions.

4. Case study

4.1. Territorial framework

Acireale is a small city of about 52000 inhabitants located in the south of Italy, in the east of Sicily. It is part of the Metropolitan Area of the city of Catania, which is about15 km away. It is a city with a high touristic vocation, very well known for its carnival, its baroque architecture and the natural reserve of its promontory called "La Timpa". The municipality of Acireale has many essential services and facilities, its own hospital, several primary and secondary schools and its own catholic diocese: consequently, it can be considered a pivot for the close municipalities and small-towns which, due to this centrality, form the so-called "hinterland *acese"*. The spatial distribution of the population and urban activities sees a greater concentration in a quite small central area and a growing dispersion with moving away towards the periphery (Fig. 3a), where population is concentrated in small urban fractions, with a significant altitude difference among those located on the eastern coast and the one over the hills.

4.2. Base scenario: Current urban public transport service

Acireale is characterized by a high modal share imbalance in favour of private vehicles (74%), followed by pedestrian mobility (18%) and public transport (7%) (PUM Acireale, 2015). The urban public transport in the Municipality of Acireale is operated by the Azienda Siciliana Trasporti (AST) company, which also manages some suburban lines. The demand for public transport has always been fragmented with time slots characterized by peaks and other time segments in which the use of public transport is scarce; moreover, there are several low-demand areas. The comparison to cities similar to Acireale by size, number of inhabitants, shows an average supply of public transport (Ignaccolo et al., 2020).

The organization of the urban public transport lines has been updated in 2019, with a rationalization of the number of lines and their routes and a new timetable implying a slight improvement of frequencies, but still with headways at common stops over half an hour. There are currently 3 urban bus lines, which share their terminal at the Railway Station (Fig. 3b):

- The red line, which serves the hospital located in the west area;
- The blue line, which serves the small town of Aci Platani in the south-west;
- The green line, which serves the small sea-town of Capomulini.

The service is unreliable from several points of view: 1) it is operated with a restricted number of vehicles that would not guarantee its operation in the event of breakdowns; 2) no real-time information is provided to users about the status of the service; 3) during the past years the company providing the service has shown poor reliability, especially in peak-off times.

Besides, there are no systematic data regarding the current demand of public transport as the new layout has recently been established and no surveys have been conducted yet.

5. Results and discussion

5.1. Evaluation of current AIs

AIs have been evaluated following the procedure in Section 3.1; since the study focuses on urban accessibility, only AI for the urban transit bus network has been taken into account. The zoning used consists of a grid of 3310 square zones of 100 m × 100 m (Fig. 4a). The AI values have

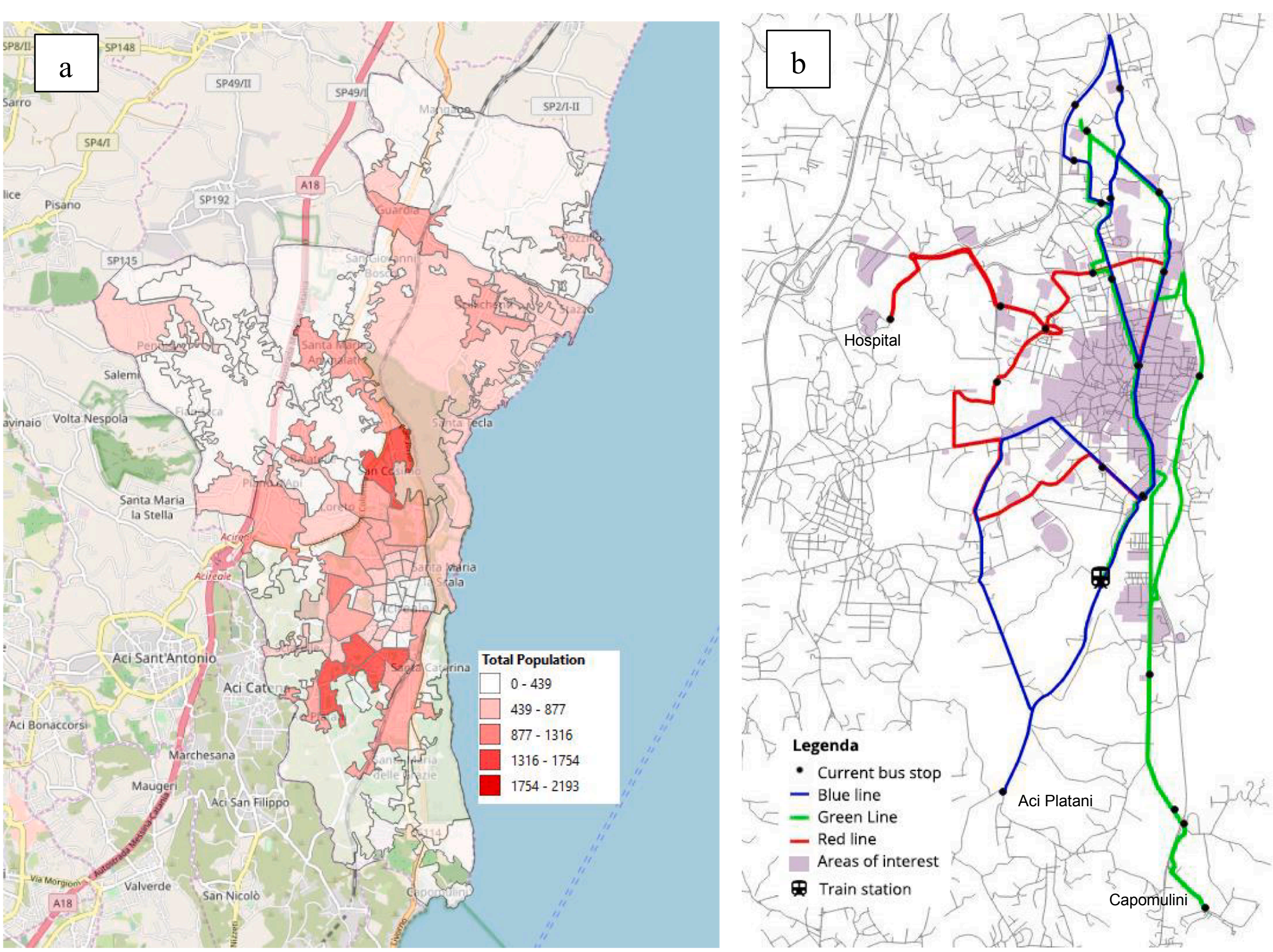

Fig. 3. (a) Thematic map of population in Acireale; (b) current urban public transport network and main POIs.

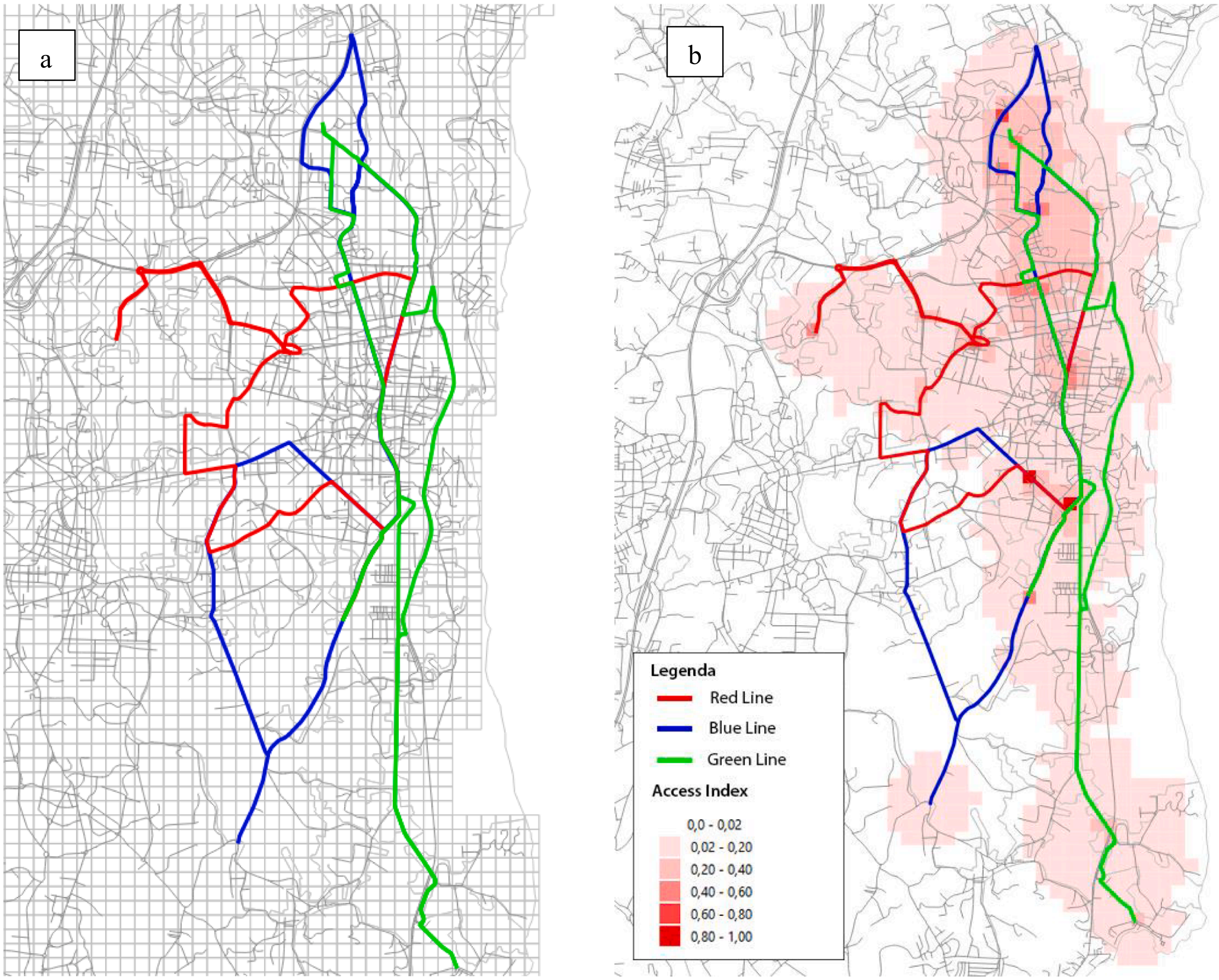

Fig. 4. (a) Zoning grid; (b) AI for the current public transport network.

been normalized between 0 and 1 and 6 accessibility classes have been used; they are represented by a chromatic map built through the use of QGIS software (Fig. 4b), where the intensity of the colour is graduated with the AI's value for each cell of the grid. The map shows a higher accessibility in the historical centre and acceptable values in areas covered by at least two of the three urban bus lines, while lower values are recorded in the more peripheral areas.

5.2. Project scenario: Proposal of public transport service and DRST service

The new proposal aims at encouraging the use of public transport in all the urban areas, and to promote intermodality with the railway station (which connects Acireale to its chief town Catania), assuming the economic funding unchanged. The intervention criteria for the choice of the new solution are based on the increase in reliability and frequency, and consequently punctuality, through a reorganization of the scheduling, favouring the temporal coverage of the service and taking care to minimize waiting times in correspondence of the railway station. The reorganization of the lines also considers the consolidated low demand present in the more peripheral areas that are currently connected with the historic centre (the town of Aci Platani and the hospital) and the seasonality of the line that connects Acireale to the seaside village of Capomulini. Moreover, a service in the proximity of the municipality of Capomulini is also operated by a sub-urban public transport line, capable of absorbing any demand for transport between the two towns by introducing a new stop at the seaside village.

Based on these considerations, the reorganization provides a single line relating to the Station-Center axis and connection with the main education institutes, with headways of 15 min, and integration of the coverage with a DRST service. The proposed solution achieves the objective of guaranteeing better frequencies at the railway station, precisely because all the vehicles and drivers of the previous service operate in the new rapid one, with 15-minute headways, while in the base scenario the best ones were of half an hour. On the basis of the new single public transport line, a new AI was calculated, with the aim of identifying the areas that, following the new structure, would have low coverage and establish the main points of attraction of users (*waypoints*), easily convertible in the stops of the on-demand transport service. Subsequently, through an intersect operation with the POIs located in the areas with lower AIs, the possible location zones for the DRST service's waypoints have been obtained (Fig. 5a). Besides, from the results of Fig. 5a, it appears that bus line stops, coinciding with those currently in existence, require further integration to ensure better coverage; therefore, it was decided to introduce three new bus stops (Fig. 5b).

On the basis of the new public transport asset, AIs have been calculated and mapped for the new scenario (Fig. 6a) and a thematic map of differences between the two AIs of the scenarios has been realized (Fig. 6b). From the difference map it is possible to see that more than 600 zones have increased their AIs, while in almost 450 zones it

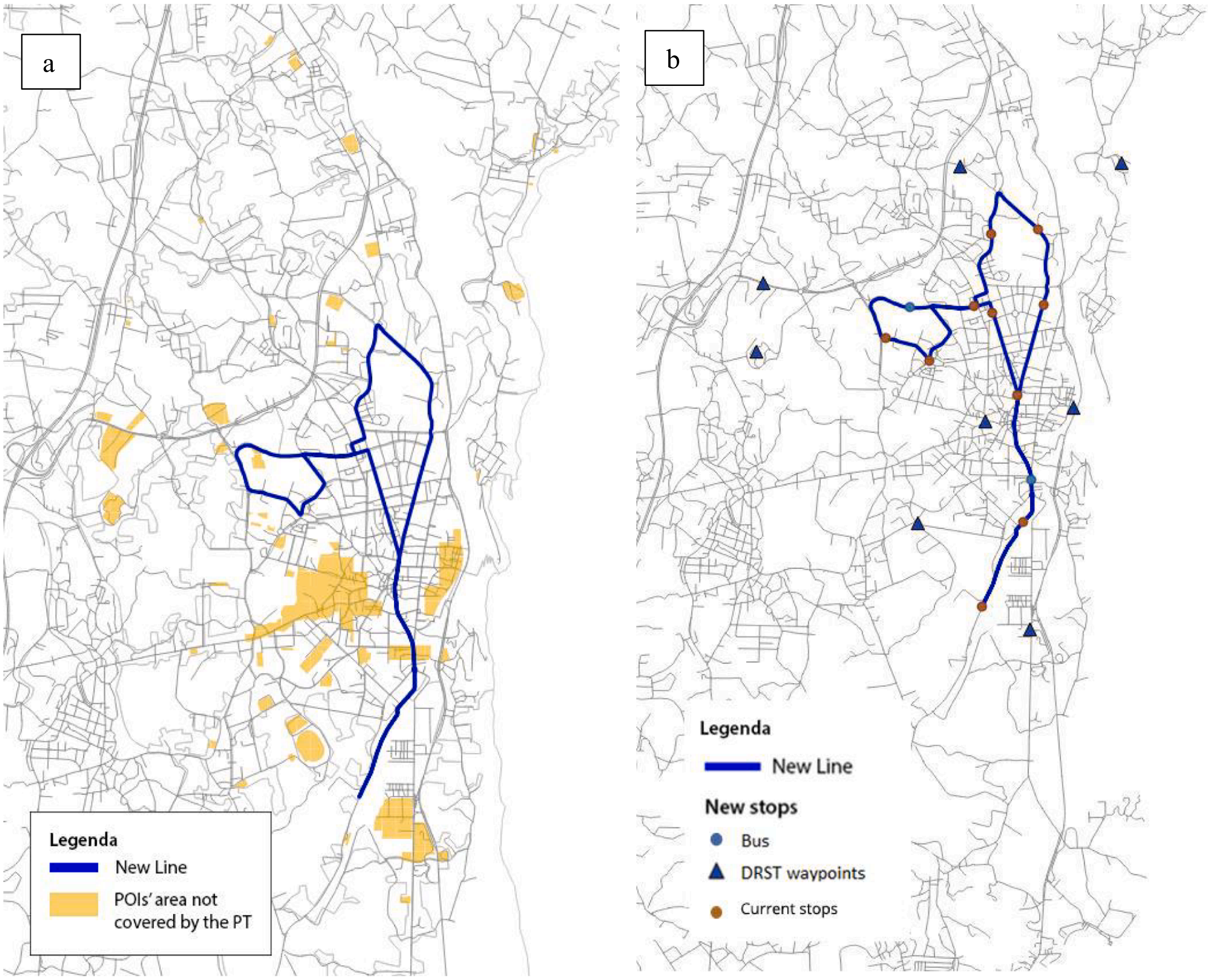

Fig. 5. (a) new PT line and areas with POIs uncovered by the PT service; (b) Proposal of waypoints for DRT service.

decreased.

5.3. Comparing accessibility improvements to social needs: Lorenz curve and Gini index

The result to be obtained following the reorganization of public transport is precisely to guarantee a greater equity in the distribution of accessibility to public transport. In this perspective, the Lorenz curve and the Gini index are used to evaluate equity condition. Lorenz Curve and Gini Index based on AIs have been calculated under the 2 scenarios. A graphical representation of Lorenz curves is shown in Fig. 7. The project scenario produces a significant improvement of equity as it is visible from the increased proximity of the curve to the perfect equity line (ideal value).

Evaluation of Gini indexes, which results are showed in Table 1, confirms the previous results showing an improvement of the project scenario quantifiable as a decrease in the Gini index of approximately 18% (it means less inequality).

Starting from the analysis of some data available for the municipality of Acireale on the presence of conditions of social disadvantage, it is possible to verify that in particular no weak social category has been disadvantaged due to the introduction of the new service. In particular, the available data for the analysis were: 1) elderly people (aged $>$ 70 years old); 2) unemployed; 3) families with more than 6 members (Fig. 8)

Comparison of maps in Fig. 8 with average changes in AIs in Fig. 5b shows that an area located in the north of the historic centre could make weaker categories experience a worsening in terms of accessibility, in particular in the case of elderly people. This issue should be particularly taken into consideration when designing the new rapid line, e.g. thinking about the introduction of a type of on-demand service dedicated to this category of users. In any case, given that technology is a key enabler of such on-demand services, the category of the elderly is the one that must be taken more carefully into consideration when planning the service booking, for example by introducing the possibility of a different method (Scheltes and de Almeida Correia, 2017) in order to guarantee their transport inclusion (Lucas, 2012). Finally, particular attention must be paid to the economic affordability of the service, as the weak social categories (such as the ones considered in this study) may also be those with a lower purchasing power: the service should be guaranteed also to low income categories, by providing special discounted fares, as usually done also for conventional transit (Inturri et al., 2020).

5.4. Discussion and policy implication

Results show that the introduction of an on-demand service would improve the distribution of accessibility although reducing the coverage of the traditional service; this is mainly due to an increased reliability of the service, addressing the specific demand needs of potential users and avoiding empty trips. This results can aid decision-makers in the design of public transport network and operation, suggesting the introduction

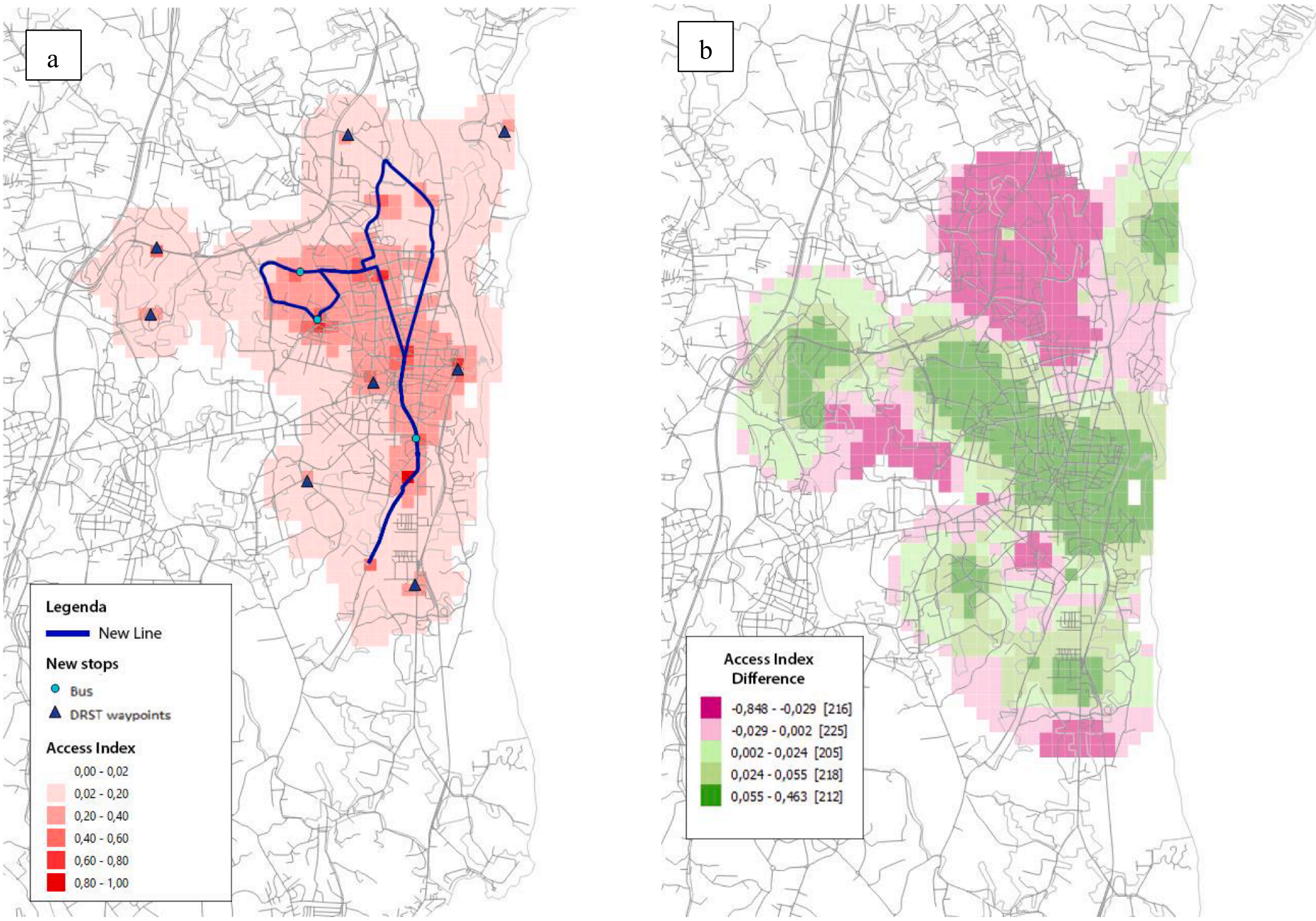

Fig. 6. (a) AI for new proposal; (b) difference between AI in the 2 scenarios.

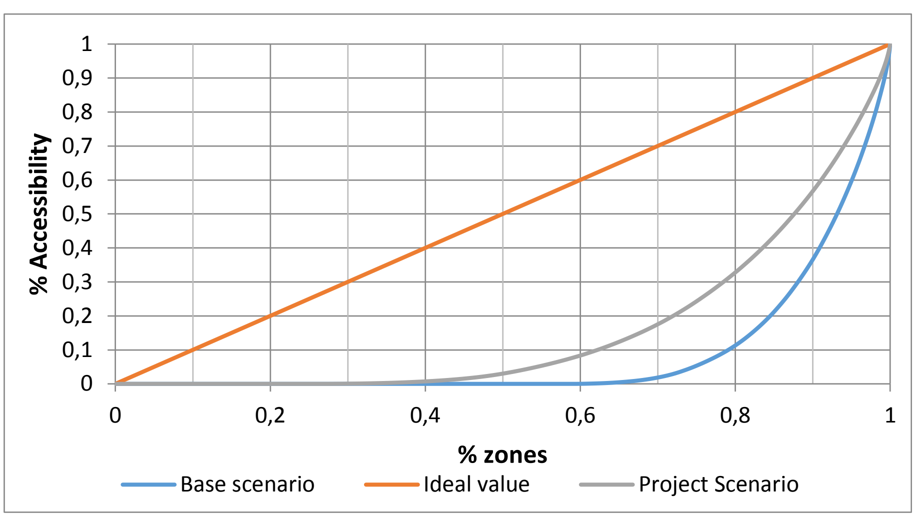

Fig. 7. Lorenz curve for base and project scenario.

Table 1
Gini index.

Scenario	Gini index
Ideal Value	0
Base scenario	0819
Project scenario	0,674

of on-demand services in small cities with attraction poles located in the town centre and dispersed areas with low mobility demand as a tool to overcome financial shortages. In this perspective, the collaboration of public transport companies with existing public services on demand (e. g. taxi and rental with driver) or the creation of PPPs with private companies can help in case the demand service cannot be financed with resources dedicated to the traditional transit. This framework is also easily understandable for non-expert stakeholders involved in the

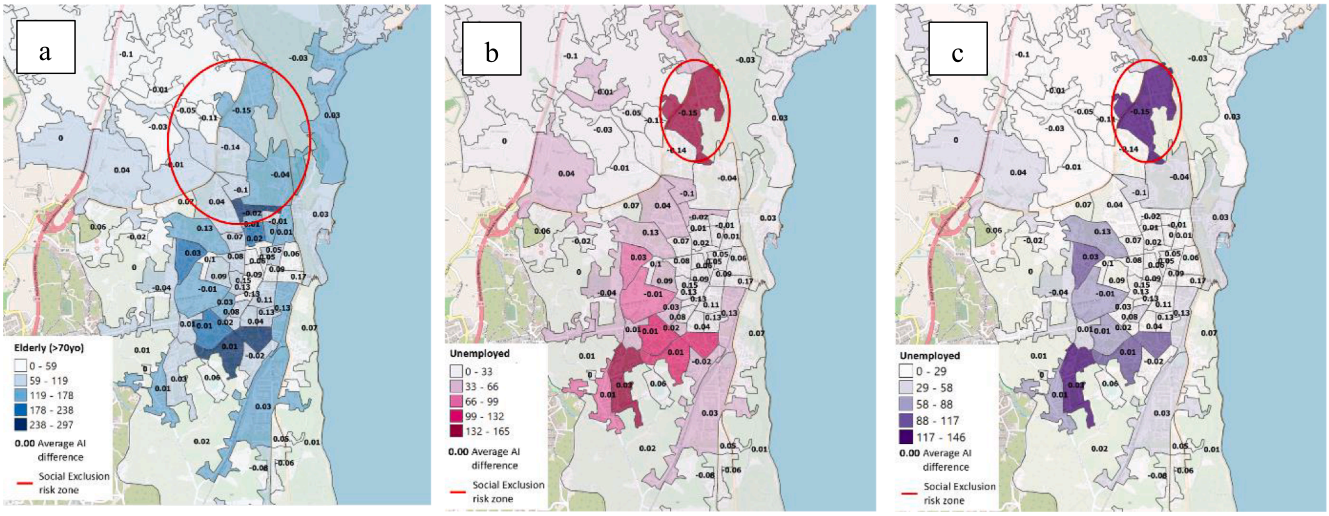

Fig. 8. a) elderly people (aged >70 years old); b) unemployed; c) families with more than 6 members. Source: own elaboration from ISTAT (2011).

decision-making process (Le Pira et al., 2016).

6. Conclusion

This paper addressed the problem of guaranteeing an efficient and effective public transport service in small urban areas via the introduction of flexible services enabled by new technologies. A methodology based on a spatial analysis was applied to the case of Acireale (Italy), a small town of about 52000 inhabitants in South Italy, to support the rationalization of conventional public transport and the design of a new flexible transport service, taking care of social exclusion issues. Scenario analysis was based on the evaluation of an Access Index, the mapping of accessibility and the evaluation of an economic index, the Gini coefficient, used to evaluate the distribution of accessibility among population. Results demonstrate that social equity can be improved by the introduction of this new type of service although the reduction of the coverage provided by traditional services. This study represents the first step of a wider research aimed at investigating the economic feasibility and operational design of DRST services, as complementary public transport services. Future research will focus on economic aspects, such as the costs of the responsible entity, e.g. associations of operators authorized to carry out passenger transport services, on the technological platform that would enable a direct connection between users and the service, and the fleet control centre of vehicles. This framework based on spatial considerations and evaluation of simple indicators, can be useful in contexts of scarce resources, like small towns or low demand areas. Nevertheless, it could be easily extended and replicated in other contexts where an integration of different services (conventional and flexible public transport, shared micromobility) could be conceived following the concepts of intermodality. In this respect, this research also goes in the direction of considering transport as Mobility as a Service (MaaS), providing seamless transport services and reducing the burden of car dependency.

7. Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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