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Elderly Mobility

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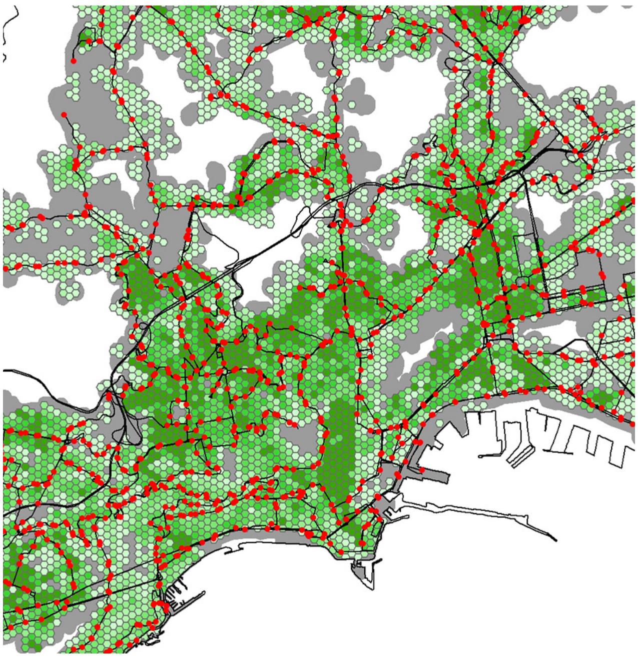

MEASURING WALKING ACCESSIBILITY TO PUBLIC TRANSPORT OF THE ELDERLY:

THE CASE OF NAPLES

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ABSTRACT

Demographic ageing represents an essential challenge for local authorities and public transport providers. Decision-makers should not ignore the specific needs of this weak segment of the population and should implement appropriate policies. This paper develops a GIS-based method to analyse public transport accessibility of elderly people to support policies and planning strategies. To test the proposed method, we propose an application to the city of Naples in Italy. We selected this study case because it represents an example of high population density, complex urban structure and low level of quality of life, especially for the elderly. The application to the city of Naples showed that the urban accessibility changes dramatically for different age segments. Results also reveal patterns of public transport coverage that are significantly low particularly in suburban settings.
The structure of this paper is organised into four sections: in the first section, we introduce the main topic of mobility of elderly; in the second section, we describe and discuss the GIS-based method proposed; in the third section, we report on the application to the city of Naples; in the last section, we analyse the results and discuss future research developments.

KEYWORDS

Elderly mobility; GIS; Public transport system; Accessibility

1 ELDERLY MOBILITY AND ACCESSIBILITY IN URBAN AREAS

Demographic ageing is an increasing phenomenon in urban areas. In Europe, the share of people aged 65 years and over is expected to increase from 19.4% in 2017 to 30% of the total population in 2060 (Eurostat, 2018). Indeed, the elderly represent an essential group of interest considering their significant increase in number as cities population continues to age. The growing number of people living with an age over 65 who lead an active lifestyle represents an essential challenge for local authorities and public transport providers in urban contexts. Not just the number of elderly population is an issue, but also its distribution in urban areas. In the past, elderly people mostly lived in central urban areas. This was due to an age-specific migratory process when young families moved to suburban fringes. Currently, the spatial distribution of elderly people is uniform in metropolitan areas (Fobker & Grotz, 2006). This phenomenon constitutes a challenge for local authorities, which should provide essential services for that specific group of the population. In particular, studies showed that mobility and accessibility trends of the elderly are a critical trial to transport systems (Aceves-González et al., 2015; Buehler and Nobis, 2010; Currie and Delbosc, 2010; Voss et al., 2016). On the other hand, the provision of a sustainable transport system, designed for the elderly's mobility needs, is both urgent and necessary (O'Neill, 2016).

Indeed older individuals suffer from weakening skills that may negatively affect their ability to move and to use different modes of transport. While car use appears to be a powerful mobility enabler, the challenge of reducing car ownership and usage is an environmental goal (Morency et al., 2011; Paez et al., 2007). Public transport companies and local authorities should prioritise the specific needs of this portion of the population and should implement appropriate policies to promote sustainable transport modes for the elderly. To support the mobility needs of elderly, one key policy would be to develop sustainable accessibility policies (Geurs & Wee, 2004; Salata & Yiannakou, 2016) and improve public transport accessibility for this segment of the population. In the last years, scholars focused extensively on equity and social inclusion as essential goals in urban and mobility planning, with a particular emphasis on the role of public transport in assuring social inclusion for the elderly population. Thus, it is essential to understand the influence that transport disadvantage and social exclusion have on a person's well-being (Delbosc & Currie, 2011). It is crucial to provide decision support tools to local administrator to evaluate and assess the social inclusion level in urban areas. In order to contribute to these debates in literature, this paper proposes a GIS-based decision support tool to measure the walking accessibility to the public transport services for elderly and provides an application to the metropolitan area of Naples in Italy.

This paper is a part of the research project 'MOBILAGE. Mobility and ageing: daily life and welfare supportive networks at the neighbourhood level', funded by Fondazione Cariplo and that involves the University of Naples, the University of Groningen and the Polytechnic University of Milan. The project is targeted to develop strategies and decision-making tools for improving the location of services for the elderly and their accessibility using public transport. The structure of the paper is organised into four different parts. Following this introduction, a GIS-based procedure is proposed to analyse the coverage of public transport systems for elderly; in section 3, we discuss the application to the city of Naples; in section 4, we analyse the results and discuss further research developments.

2 METODOLOGICAL NOTES

In this study, we use a contour accessibility measure, adding some improvements to the original formula. In particular, we enhance it with the demographic characteristics of elderly users, with the level of service of public transport (service frequency) and the urban morphology (the walking streets network and its slope) (Wang & Cao, 2017).

In general, 'contour accessibility measures' identify catchment area using the average walking distance or walking time to reach the transport hubs. In several applications, buffers of 400m around bus stops and 800m around rail stations are commonly used to identify the area from which most transit users will access by walking (El-Geneidy et al., 2013; Masoumi & Shaygan, 2016; Weinstein Agrawal et al., 2008; Zhao et al., 2003). One difference we apply in this study is that we consider the network walking distances, measured on the actual walking network, and not the Euclidean buffers (circular buffers around a point) (Gutiérrez & Garcà-Palomares, 2008).

Another improvement from the original contour measure formula is that we hypothesise that catchment radius of a public transport stop is dependent on the frequency of the public transport service provided at that stop, following the principle that customers are willing to walk more to access a higher-frequency transit service (Ryan et al., 2015). Accordingly, the coverage of transport service of high-frequency routes is larger than the one offering lower-frequency routes (Alshalalfah & Shalaby, 2007). Finally, another factor we consider is how walking speed changes with the customers' age. Bohannon and Andrews (2011) revealed that walking speed declines with age. Accordingly, we consider a walking speed that is dependent on public transport users' age.

We divided the study into hexagonal cells with the side length of 50m that provides high accuracy in the graphical and numerical results. In literature, the use of a hexagonal cell rather than a square one is best advised for dealing with the measurement of shorter walking paths (Kibambe Lubamba et al., 2013). We then assigned to each cell the population of different age segments, using the cover surface of buildings (Carpentieri and Favo, 2017).

Firstly we proportionally transferred the number of inhabitants of the census track to the buildings located in each census track. Then we calculated the total number of inhabitants for each hexagonal cell as the sum of inhabitants living in the buildings located in each hexagonal cell (see Figure 1).

Fig. 1 Hexagonal cells, census tracts and building surfaces

Accessibility of a cell d and for different age segments has been calculated according to the following formula:

$$A_{dAGE} = \ W_{dAGE} \cdot P_{dAGE}$$

where:

$W_{dAGE} = 1 \; if \; d_d < d_{frAGE}; \;\; d_d = 0 \; otherwise$

$d_{frAGE} = \ T_{fr} \cdot s_{AGE}$

$T_{fr} = \alpha \cdot fr$

$s_{AGE} = \beta \cdot AGE$

where

P_{dAGE} is the population in the cell d of a specific age segment

d_{SAGE} is the distance users are willing to walk measured on the walking network

T_{fr} is the walking time users are spending

fr is the public transport service frequency in the closest station to the cell

s_{AGE} is the walking speed for different age segment

α, β are two calibrated parameters

The proposed GIS-based procedure is organised in three main steps: (1) Data collection, (2) GIS analysis and (3) Visualization of results. Using the ERSI GIS Model Builder tool of ArcGIS Pro 2.2 software, we defined the geoprocessing workflow used to execute operations that organise and analyse the alphanumeric and spatial data (see Figure 2). In Step 1, datasets are uploaded in the GIS. In Step 2, geoprocessing, data and network analysis operations elaborate the data to obtain the quantitative and spatial outputs. In Step 3, maps and tables obtained to visualise the results of the analysis. We used the ESRI ArcGIS Pro 2.2 (for collecting, geoprocessing and analysing the data) and the Network Analysis tool of ESRI to calculate the bus stops catchment area, considering the attributes of surface elevation (slope), walking speed of each user age category and time of access to bus stops.

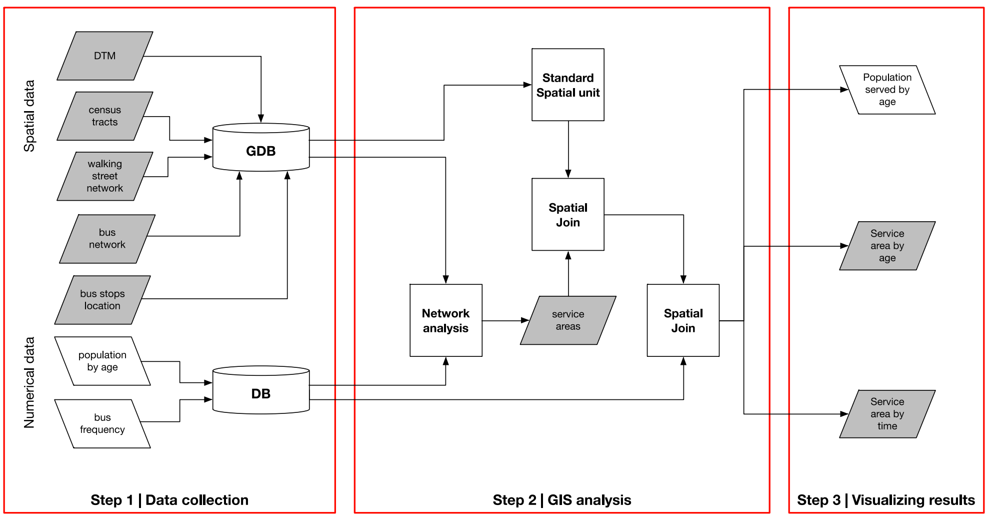


Fig. 2 Workflow diagram of the GIS-based procedure

3 THE APPLICATION TO THE CITY OF NAPLES

To test the methodology, we applied it to the city of Naples, which represents an interesting case study because of its high population density, its non-uniform urban structure and its increasing ageing population. The city of Naples has 970,185 inhabitants (ISTAT, 2017) living in 117.27 km² and is the fifth Italian city regarding population density. In the last twenty years, the city has been affected by a gradual increase in the elderly population. As of 2017, the number of elderly people was 186,812 (20% of the total population). For this study, we considered only the bus routes served by the Mobility Company of Naples (ANM), because GTFS open data were available only for this service . The ANM operate about 90% of urban bus trips in the city of Naples (City of Naples, 2016). This service consists of 306km of urban lines and 111km of suburban lines. We considered the 1.867 bus stops located within the administrative city area boundaries and the services from 6:00am to 2:00pm of a weekday (see Figure 3c).

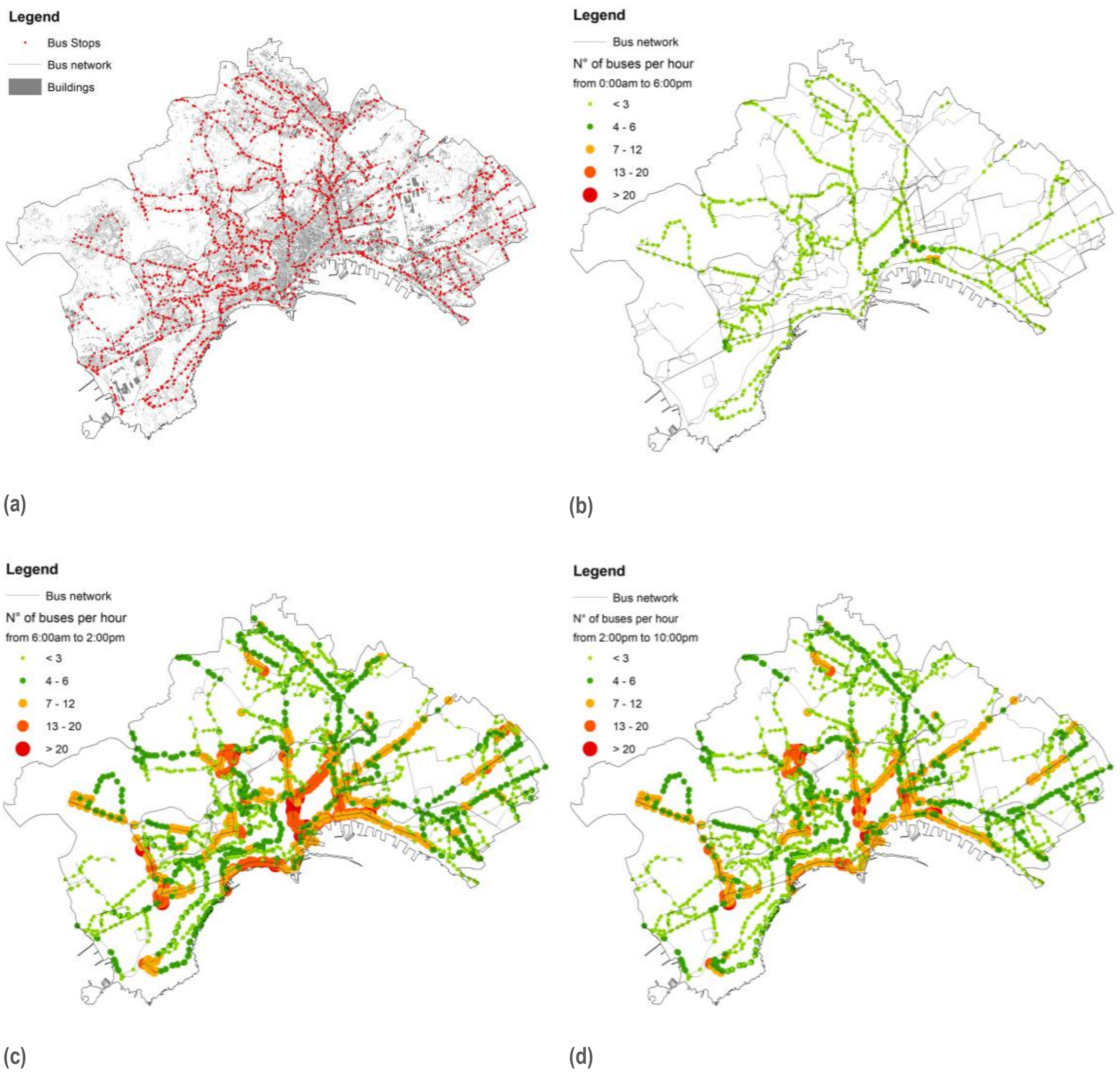


Fig. 3 The bus network of the city of Naples (a) and the bus frequency for each stop in the different time intervals: from 0:00 am to 6:00am (b), from 6:00am to 2:00pm (c); from 2:00pm to 10:00pm (d)

According to national commuting census of 2011 run by the Italian National Institute for Statistics (ISTAT, 2011), the average daily commuting in the city of Naples is 342,109 trips, with the following modal share: 1.1% by rail; 17.6% by bus; 33.6% by car and motorcycle; and 37.7% by other means of transport (ISTAT, 2011). In Naples, it is possible to identify different urban patterns, morphological patterns, and socio-economic characteristics. The historical area is located in the city centre , which has high population density and high accessibility to public transport services (metro and bus). The peripheral areas were developed during the 19th and 20th-centuries and have low accessibility to public transport services and are mostly residential.

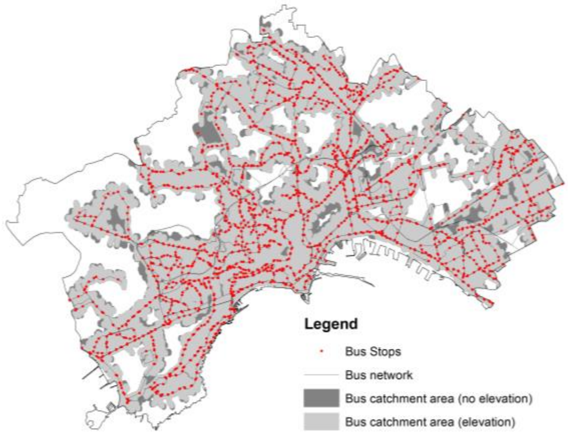
In our analysis, we used spatial and alphanumeric datasets from the different open sources. In particular, we used the data on the bus network produced by the Naples bus service provider (ANM). The demographic data were extracted from the ISTAT (2011). The Digital Terrain Model and the Buildings polylines are from the Web Coverage Service (WCS) provided on the open access National Geoportal owned by the Italian Ministry of the Environment and Protection of Land and Sea (available at http://www.pcn.minambiente.it/). We created the road network through the topological correction of the Open Street Map database. Table 1 provides the list of alphanumeric and spatial input datasets (vector and raster) used. Another source of data was the Moovit Public Transit Index data.

DATA	CATEGORY OF DATA	TYPE OF GEOMETRY	SOURCE	YEAR
Population	Alfa-numeric	-	ISTAT	2011
Bus stops	Vector	Point	Naples public transport company (ANM)	2018
Road network	Vector	Polyline	Open Street Map	2011
Bus network	Vector	Polyline	Naples public transport company (ANM)	2018
Census tract	Vector	Polygon	ISTAT	2011
Buildings	Vector	Polygon	National Geoportal	2011
Digital Terrain Model	Raster	-	National Geoportal	2017

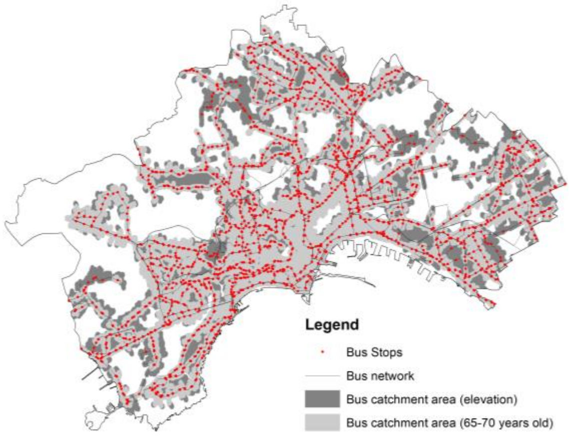
Tab. 1 Data used to application to the City of Naples application

Figure 4 shows the walking catchment area of the bus stop network. In particular, it displays the different catchment areas considering of not the slope of the road network (Figure 4a); it also shows the bus network coverage for different age groups and different walking speeds (Figure 4b, 4c and 4d). We consider three different age groups: from 65 to 70 years old (young elderly), from 70 to 75 years old (medium elderly) and over 75 years old (old elderly).

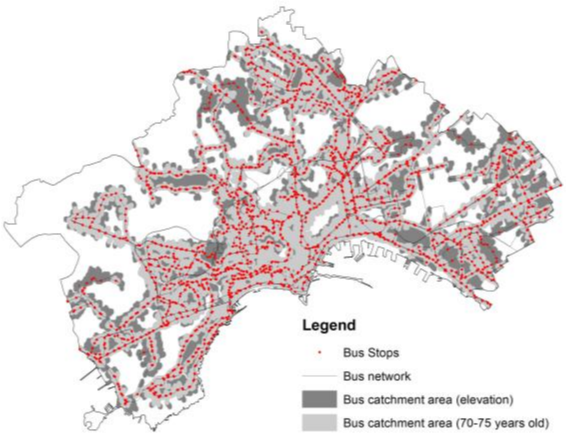
The maps show a significant difference between the catchment areas with and without the slope attribute for the three elderly age groups considered. In particular, the analysis evidences a reduction of 18% (12.7 sq.km) of the catchment area without the slope for the elderly people from 65 to 70 years old compared to the catchment area with the slope. In the case of the catchment areas for elderly people over 75 years, the difference is almost 33% (22.8 sq.km).



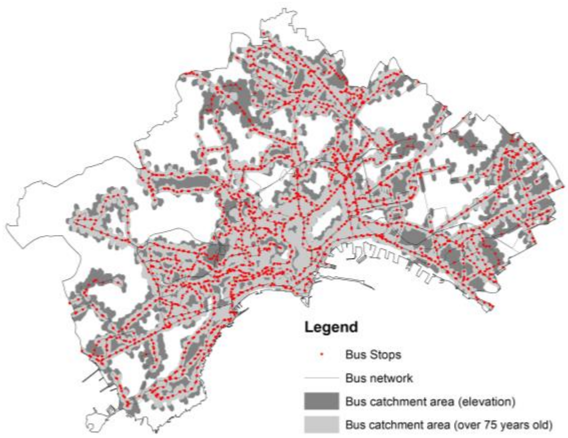
(a)



(b)



(c)



(d)

Fig. 4 The comparison of bus catchment areas with and without the slope parameter for an middle age user (a) and for different elderly age categories: 65-70 years (b), 70-75 years (c), over 75 (d)

Figure 5 shows that almost 89% of the total population is located in the bus catchment area if we do not consider the actual walking network slope (no elevation). Considering the slope parameter (with elevation), the total population is limited only at the 8% (67,322 inhab.). This demonstrates how crucial is to take into account the real walking condition, especially in a particular context as the city of Naples. The analysis also provides evidences that over 32% (59,072 inhab.) of elderly people over 75 years old live in areas that are not covered by bus services.

Table 2 summaries main results from the accessibility analysis. In details, 20,680 inhabitants between 65 and 70 years old do not have easy access to bus services in Naples, which correspond to 36% of the total population; 11,100 inhabitants between 70 and 75 years old do not have easy access to bus services that correspond to the 27% of the total population.

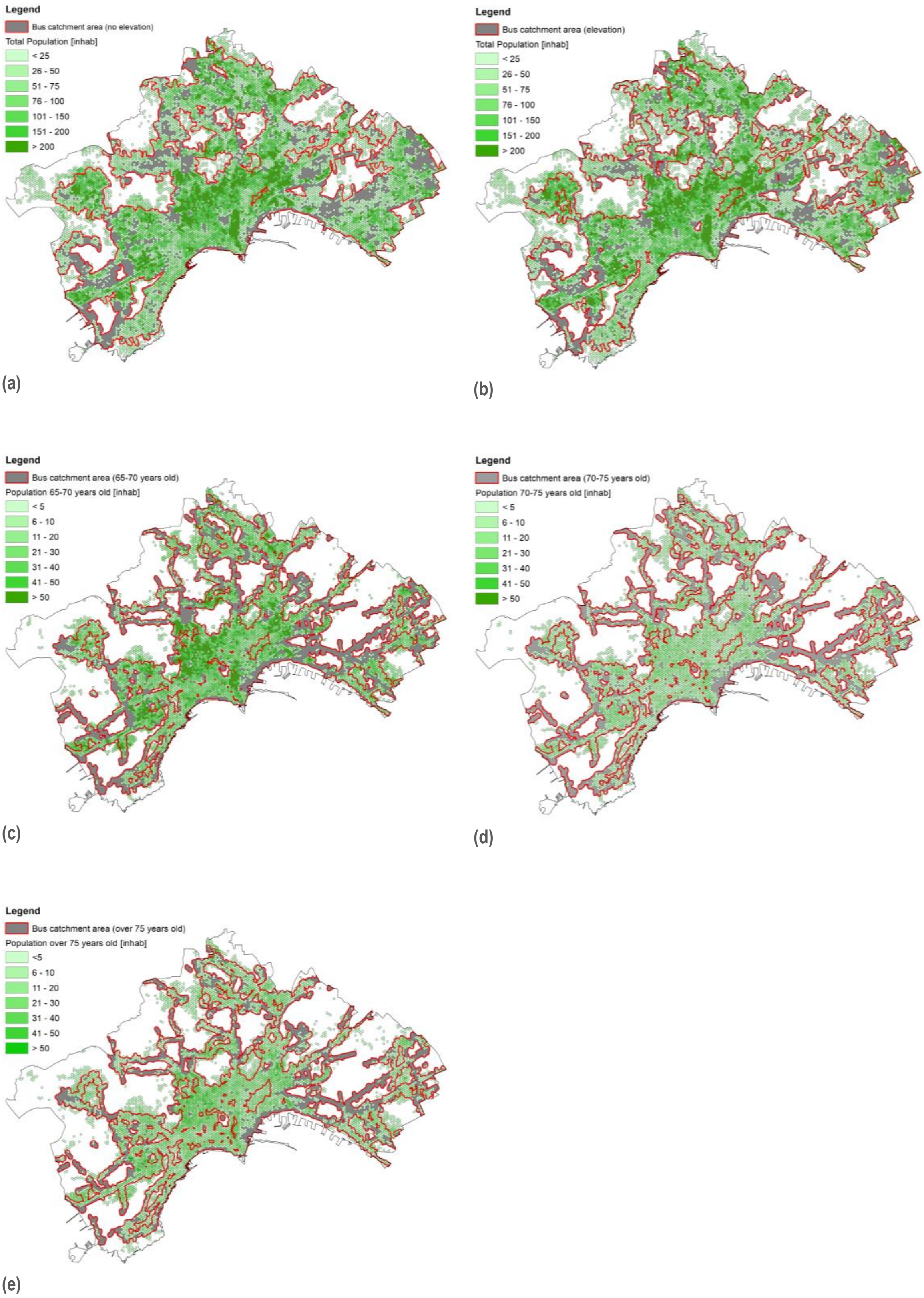


Fig. 5 Accessibility for the different elderly age groups: between 65 and 70 years old (c), between 70 and 75 years old (d), and over 75 years old (e)

AGE INTERVAL	BUS CATCHMENT AREA	NUMBER OF INHABITANTS	NUMBER OF INHABITANTS WHO LIVE IN THE BUS CATCHMENT AREA	NUMBER OF INHABITANTS WHO LIVE OUTSIDE THE BUS CATCHMENT AREA
-	[sq.km]	[inhab]	[inhab]	%
Total inhabitants (no elevation)	81.5	961,106	861,234	10%
Total inhabitants (elevation)	70.8	961,106	793,912	17%
65 - 70 inhabitants	58.1	56,835	36,155	36%
70 - 75 inhabitants	52.1	41,001	29,901	27%
Over 75 inhabitants	48.0	84,928	57,636	32%

Tab. 2 Results of application of GIS-based procedure to the city of Naples

Some peripheral neighbourhoods (Piscinola, Marianella, Chiaiano, Scampia) have a higher percentage of elderly people unserved which exceeds 50%. The percentage of inhabitants between 65 and 70 years old the percentage of inhabitants who lives outside the catchment area is 20% in all neighbourhoods. The neighbourhoods with higher percentage of elderly people within the catchment areas of bus service are Chiaia, Posillipo, S. Ferdinando, which are all located in central areas. In particular, in these neighbourhoods the percentage of inhabitants between 70 and 75 years old covered is over the 90%.

3 CONCLUSION AND FUTURE DEVELOPMENTS

The growth of the elderly population in the last decades has generated a serious accessibility exclusion phenomenon. Some aspects influence the accessibility for the elderly population. This study provides evidences how this is particularly true in the city of Naples. The study of scientific literature on the relationship between catchment areas, transport service frequency and age of users revealed the importance of considering these aspects in the evaluation of public transport accessibility. We develop a GIS-based procedure to evaluate the extension of public transport catchments areas by using open datasets. The results of the application show that the level of transport exclusion for the elderly population is twice the value calculated for the entire population. Results also show great difference of essential public transport services for elderly people between the richer central areas and the suburban settings. It would be crucial to address transport investments and policies towards reducing the transport exclusion in these areas.

Therefore, we suggest the following research directions for further research: (1) to add other variables in the analysis and in particular the security of bus stop, the connectivity of bus lines, the road walking quality; (2) to add to the metro service catchment area to our analysis; (3) to improve the used accessibility measure and calculate a potential accessibility measures, adding the location of activities and services of interest for the elderly people; (4) to apply the GIS-based procedure to the City of Milan; (5) to develop a web GIS tool to support the public administration and transport company.

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