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Health services and Network analysis to assess the spatial accessibility (Sardinia, Italy)

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Abstract: Population ageing is the most pervasive and dominant global demographic trend of our time. The number of people aged 65 and over worldwide is expected to more than double from 2021 to 2050. The EU population is also ageing, and Italy recorded the highest median age of the population in 2022. Changing demographics shape urban governance, especially in terms of the provision of urban services, such as healthcare facilities. Within this framework, the study proposes a methodological approach to evaluate spatial accessibility to health services, considering the daily needs of a growing elderly population. We take the Italian island of Sardinia as a case study.

Keywords: health services; spatial accessibility; network analysis

1. Introduction

Population ageing is the most pervasive and dominant global demographic trend of our time [1]. According to the latest World Social Report [2], the number of people aged 65 or older worldwide is expected to more than double, from 761 million in 2021 to 1.6 billion in 2050. The EU population is also ageing: the number of people aged 80 years and older has increased in all Member States in 2022 (Eurostat, 2023). Half of EU's population older than 44.4 years. Italy is one of the countries with the oldest population, recording the highest median age of the population in 2022 (48 years).

According to these trends, the emergence of an inverted population pyramid will be a real challenge for human development in the future. Changing demographics will also shape urban governance, especially in terms of the provision of both social services of general interest and specialized urban services. As a matter of fact, the "silver economy", i.e. the consumer economy that characterizes the population of 50–65-year-olds, up to the over 65s, requires a specific system of services. Among these, health, and welfare services, as well as housing, represent primary services to be guaranteed, also in terms of adequate spatial accessibility.

This is a real challenge, especially in Italy, where fragile territories, characterized by important geographical or demographic disadvantages, cover a total of 60% of the entire national territory, 52% of the Municipalities and 22% of the population.

The National Strategy for "Inner Areas" (SNAI) (2014) defines a polycentric structure of the Italian territory, characterized by a network of urban centres, around which the remaining municipalities gravitate recording a different level of accessibility [3], calculated in terms of minutes of travel to the nearest hub. According to the SNAI, a hub is a municipality or an aggregation of municipalities on which the provision of essential services for citizens is concentrated: secondary school; hospitals with a Department of Emergency and Acceptance (DEA) level I; Platinum, Gold or Silver train stations. These municipalities are classified according to the related degree of spatial peripherality: peri-urban areas ($t < 20$ minutes); intermediate areas ($20 < t < 40$ minutes); peripheral areas ($40 < t < 75$ minutes); ultra peripheral areas ($t > 75$ minutes). The last three categories are defined

as Inner Areas. Here, significant investments in territorial resources and accessibility are needed to counter marginalization and the phenomena of demographic decline.

Several authors analyze the relationship between the quality of healthcare and the value of the main demographic indicators, including longevity, life expectancy at birth, but also mortality [4-5]. Considering that timely access to facilities is crucial, other studies propose methods to assess the potential travel times needed by the population to reach health services [6].

Within this framework, the paper proposes a methodological approach to evaluate accessibility to healthcare facilities taking the Autonomous Region of Sardinia (ARS) (Italy) as a case study. The study uses Network Analysis (NA) techniques to analyze the spatial distribution of the population (post-COVID-19, to 2022), particularly the elderly population (> 65 years), in the urban centers and in the internal areas of Sardinia, assessing therefore the level of private and public accessibility to healthcare facilities.

The paper is part of the e.INS project, which promotes sustainable transport model to improve the internal and external regional mobility (to and from Sardinia), also for health purposes, in line with the concept of Mobility as a Service (MaaS) [7].

The manuscript is organized as follows: Section 2 - Area of study, provides a description of the health services system in the ARS; Section 3 - Methodology, describes NA techniques used to analyze the spatial distribution of the population and the accessibility to healthcare facilities; Section 4 - Results and Conclusions.

2. Area of study

Main Sardinia is an Italian region of 1,578,146 inhabitants (2023). With a surface area of 24,090 km², it is the second largest island in the Mediterranean, after Sicily. The ARS, established in 1948, is administratively organized into four provinces - Nuoro (NU), Oristano (OR), Sassari (SS), South Sardinia (SU) -, a metropolitan city - Metropolitan City of Cagliari (MCC) - and 377 municipalities.

As in the rest of the country, Sardinia is hit by a spiral of demographic decline: in the period between 2013 and 2023 it recorded a decline of over 85,000 inhabitants. According to ISTAT forecasts, the Italian population will decline further: from 59 million (2022) to 58.1 million (2030), to 54.4 million (2050), up to 45.8 million (2080) [8]. The decrease will be even more marked in Sardinia [9], where in 2022 the lowest level of fertility (0.95) in Italy and the minimum value of children per woman was recorded, with an average number of 0.93. Moreover, the Sardinian population is significantly older than the country's average [10]. In 2021 the regional average age is 48.1 years, higher than the national average of 46.2 years. Within this framework, the optimization of the healthcare services represents a real challenge to respond to the growing demand, especially that from the older segments of the population. There are 22 nodes in the hospital emergency network active in 2021, located throughout the regional territory (Fig. 1): n. 11 Emergency Rooms (ER); n. 8 DEA I (NU: 1; OR:1; SS:1; SU: 3; MCC: 2); n. 3 DEA 2 (SS: 2; MCC: 1).

However, the optimization of the healthcare services, especially as regards spatial accessibility, is threatened by the condition of the internal mobility and its infrastructural deficits (road and railway networks), and by a primordial condition of disadvantage typical of the islands. It is estimated that travel times for moving within the island, among the highest in Italy, further aggravate the condition of insularity [11].

3. Methodology

The methodology used to analyze the spatial distribution of the population and to measure accessibility to health services is based on the use of NA techniques that provides a comprehensive understanding of how spatial relationships and geographic factors influence the dynamics of networks [12]. Spatial network analysis involves the exploration of spatial relationships between nodes in a geographic network. Given a specific spatial typology, in which the geographical position of the nodes (points) and connections (arcs)

within the network is identified, NAs allows to assess also spatial accessibility, i.e. the ease with which a node can be reached from other points of the network, considering the spatial characteristics. In this sense, NAs are useful to define isochrones, that are maps that show the areas that can be reached within a given time interval from a starting point, considering variables such as travel speed and the road network, or the speed of public transport available. As a matter of fact, isochrones can be calculated for pedestrians, cars, bicycles, or public transport. In this sense, isochrones allow to assess the coverage of services and the level of accessibility, thus supporting urban and transport planning.

GIS (Geographic Information Systems) software and online mapping applications offer tools for generating isochrones. The Travel Time application plugin, for example, adds a toolbar and processing algorithms allowing to query the TravelTime API directly from QGIS. It allows to obtain polygons based on actual travel time using several transport modes rather, allowing for much more accurate results than simple distance calculations.

4. Results and Conclusion

'In this study, the NA techniques of the QGIS software were used to define the nodes of the hospital emergency network and the related 20-minute isochrones, to analyse the spatial distribution of the population and therefore, evaluate the accessibility to health facilities (post-Covid 19, 2022), both by private and public transport. In line with the SNAI, the regional area has been classified as follows: Urban centers, i.e. areas equipped with one or more structures of the hospital emergency network, and peri-urban areas (t < 20 min); Inner areas, which involves intermediate, peripheral and ultra-peripheral areas (t > 20 minutes). In this manuscript we present the results of accessibility to hospital emergency facilities by private means of transport and a travel speed of 50 km/h (Fig. 1).
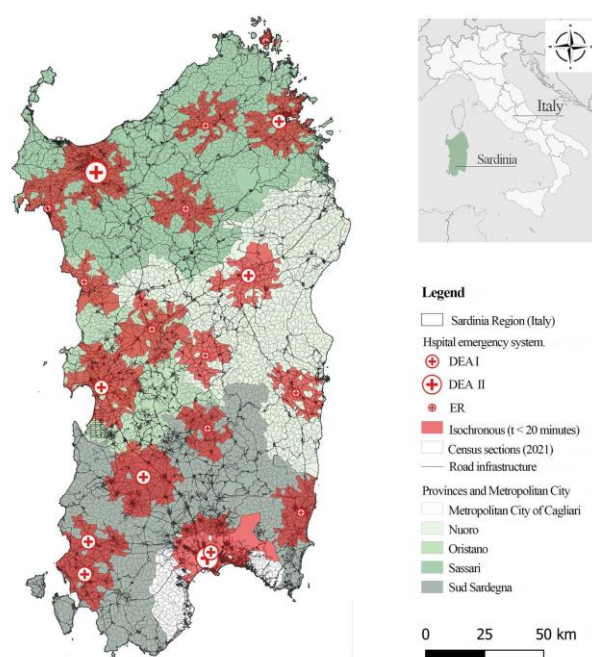

Figure 1. Spatial distribution of the population in reference to accessibility to health services in the Sardinia Region. The isochrones (t<20 minutes) referring to each node of the hospital emergency network are indicated in red (Author: Ladu M., 2024).

The spatial distribution of the population on a regional (Sardinia Region), provincial (NU, OR, SS, SU) and metropolitan city (MCC) scale reveals that 66.14% of the population lives in urban centers, while 33.89% lives in inner areas, which also host 35.05% of the regional elderly population.

In the MCC, the resident population in 2021 was estimated to be 422.499 inhabitants, of which 102,936 were elderly (24.36%). With 88.20% of residents living in urban centres, the MCC records the highest levels of accessibility to healthcare facilities, exceeding the regional average by several percentage points. The most populous province, that of Sassari, with 476,516 inhabitants, records levels of accessibility to health facilities closer to the regional average: 67.22% of residents live in urban centres, while the 32.79& in inner areas.

The lowest levels of accessibility are recorded in three provinces: Nuoro, Oristano and Southern Sardinia. As regards the Nuoro province, almost 64% of the resident population and over 63% of the elderly population live in the inner areas.

The results reflect the value of some demographic indicators: the three provinces record the lowest life expectancy values compared to the regional and national average.

According to the Fair and sustainable well-being indicators (BES), life expectancy at birth in Sardinia (82.5 years) in 2022 is slightly higher than the national value.

The MCC is the one with the highest value at a regional level (83.8 years), higher than the national average figure (82.4 years), while the Nuoro province records the lowest value (81.7 years), or almost one year less than Sardinia and Italy.

These results require particular attention, especially considering recent forecasts on demographic dynamics (2023-2031, ISTAT), which show that the population aged 65 and over will be concentrated mainly in peri-urban areas.

The methodological approach represents a useful tool to support sustainable transport planning in those areas with low levels of spatial accessibility to health services, in line with the MaaS approach. As a matter of fact, we will investigate possible solutions to integrate healthcare service and MaaS service, to improve internal mobility through a call system associated with medical booking.

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Conflicts of Interest: The authors declare no conflict of interest.

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