Regional Disparity, Accessibility, and Sustainable Mobility in Insular Contexts

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Abstract. Multiple and permanent disadvantages and social inequalities often make insular contexts more vulnerable to contingent and structural phenomena. The principle of insularity, which is already recognized in EU legislation and in the Italian constitution, requires a specific political strategy and action priorities. The Sardinia Region (Italy) represents an interesting case study. As a matter of fact, despite numerous attempts to guarantee territorial continuity, the geographical isolation still represents the greatest cost for the population. Here, internal mobility is also threatened by significant gaps in transport infrastructure, especially in the inner areas. In this sense, regional issues and regional disparity are at the core of the "e.INS – Ecosystem of Innovation for Next Generation Sardinia" project - spoke 8 - Sustainable mobility which proposes a methodological approach to improve the transport offer to and from Sardinia and within the regional territory by MaaS solutions.

Keywords: Regional Disparity · Accessibility · Sustainable Mobility

1 Introduction

Multiple and permanent disadvantages and social inequalities often make insular contexts more vulnerable to contingent and structural phenomena [1].

The principle of insularity, which is already recognized in EU legislation and in the Italian constitution, requires a specific political strategy and action priorities to face the regional disparity condition [2, 3]. This is the case of the Autonomous Region of Sardinia (ARS), in Italy, which represents an interesting case study. As a matter of fact, despite numerous attempts to guarantee territorial continuity [4], the geographical isolation still represents the greatest cost for the population of over 1,500,000 inhabitants (2023). Regional disparities can be correlated to a weak extra and intra-regional continuity (mutually shaped), due to a significant gap in transport policies (air and maritime), as well as in infrastructure and supply for internal mobility, further aggravating the condition of insularity [5].

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Regional issues and regional disparity are at the core of the "e.INS – Ecosystem of Innovation for Next Generation Sardinia" project - spoke 8, which proposes a methodological approach to improve the transport offer to and from Sardinia and within the regional territory by MaaS solutions [6].

More densely populated contexts show a greater predisposition to the development and use of MaaS solutions in their traditional form, thanks to the high travel demand, the general propensity of people to integrate available mobility alternatives, and the economic convenience of both public and private operators. However, the implementation of MaaS systems in low-density settlements, such as most of the contexts in Sardinia, needs to be studied further and requires a redefinition of the model operating conditions [7, 8]. In fact, in these contexts, accessibility depends mainly on the private car, while public transport is very weak and limited to a few time slots throughout the day or seasons. Interchanges are therefore almost always obligatory.

The benefits of MaaS, which facilitates and supports travel at all stages, from planning to booking, purchasing tickets, and navigating, are particularly useful and beneficial in inner areas [29], sparsely populated areas to reduce the mobility divide (low spatial accessibility, limited mobility alternatives, high proportion of elderly people with reduced individual abilities, knowledge, and skills to travel independently, etc.). In addition, recent applications have shown that the introduction of innovative forms of mobility services can have a positive impact on the local economy, creating new jobs and business opportunities and widening the range of available transport alternatives, thus increasing the attractiveness of places, also in terms of sustainability.

In this framework, the manuscript is structured as follows: Sect. 2 - Materials, describes the study area (the ARS) and the main objective and challenges of the e.INS project - spoke 8; Sect. 3 - Method, is dedicated to the methodological approach developed for the construction of an open-source multilevel geodatabase to support the development of a transport model in Sardinia, in line with the MaaS concepts; Sect. 4 - Results, describe the main topics selected to develop the multilevel geodatabase, according to the project targets; Sect. 5 - Conclusions, reports final considerations on the research issues.

2 Materials

2.1 Study Area

The Sardinia Region is the second largest island in Italy, after Sicily. With a population of 1,578,146 inhabitants (2023), the Island records a population density value of 66 inhabitants/ km^2, among the lowest nationally.

The progressive evolution of the administrative geography [9] has led to the current configuration which consists of four provinces (Nuoro, Oristano, Sassari, and South Sardinia), a metropolitan city (Metropolitan city of Cagliari) and 377 municipalities.

Sardinia has a significant deficit in relation to the provision and competitiveness of transport infrastructure [10], which consists of [11]:

- around 9000 km of road network (State and Provincial Roads).
- 427 km of Italian railway network (RFI) [12], in addition to which the railway network managed by the Sardinian Regional Transport Company (ARST) and the tourist railway networks (Trenino Verde) should be considered.

– 8 ports administered by the Port System Authority of the Sea of Sardinia (Cagliari, Olbia, Porto Torres, Golfo Aranci, Portovesme, Oristano, Santa Teresa di Gallura and Arbatax).
– 3 international airports (Cagliari, Olbia, and Alghero).

The past, present and future of the Sardinia Region are closely linked to the "transport" issue, in relation to external connections, and, above all, to internal connections on the island [32]. The transport system has significantly influenced various development opportunities [13], as well as the rise of tourist destinations, which nowadays face seasonal concentration of tourist flows [14].

Despite numerous attempts to guarantee territorial continuity [15], the geographical impedance still represents the greatest cost for both inhabitants and city users (Fig. 1).

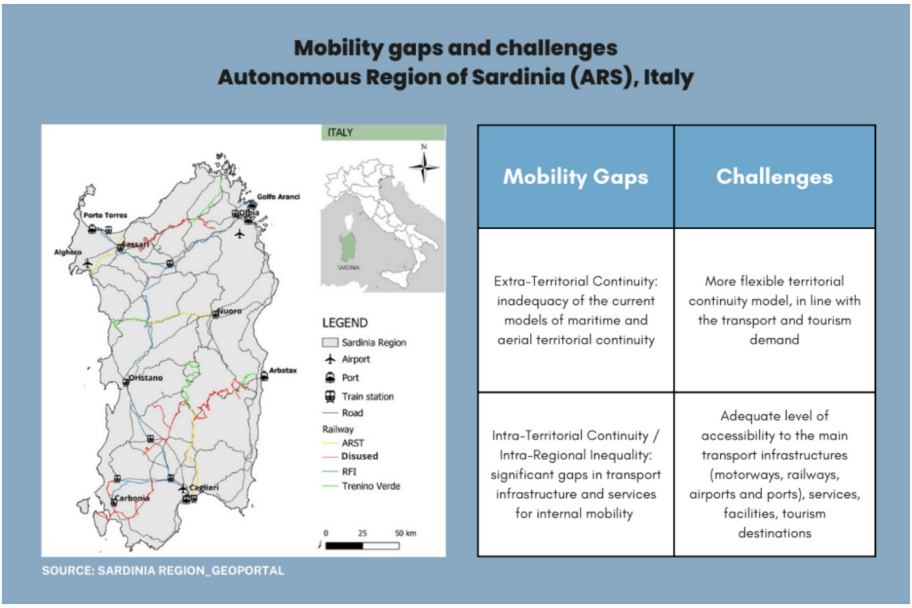


Fig. 1. Mobility gaps and challenges in the ARS (Italy). Author: Mara Ladu

Regional disparities can be correlated to a weak extra and intra-regional continuity (mutually shaped), due to a significant gap in transport policies (air and maritime), as well as in infrastructure and supply for internal mobility, further aggravating the condition of insularity [5]. As a matter of fact, transport services are essentially limited to a few rail connections (due to the limited extent of the network) and public road transport on extra-urban routes, operated by the regional company ARST and a few private subsidized companies. Urban public transport system is available in major cities. The island's settlement structure, characterized by the strong dependence of the smaller centers on the main urbanized areas (Fig. 2), has determined the structure of the transport services, which become more sparse (in terms of trips and frequency) as the distance

from the main attractions increases, making public transport less convenient and non-competitive with the private car.

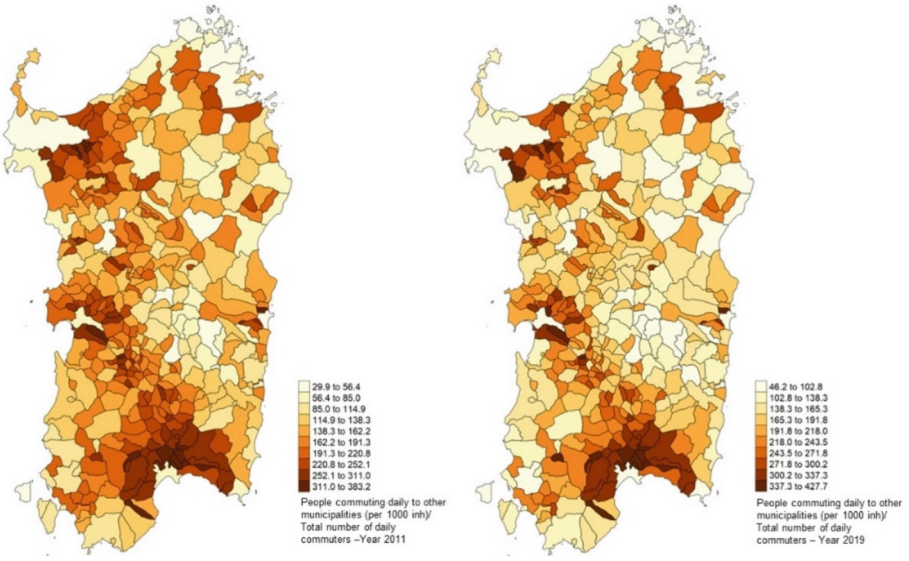


Fig. 2. Commuting flows (data source ISTAT Census 2011 and 2019). Author: Tanja Congiu

Furthermore, as in the national context, demographic decline, and the aging of the population [16], especially in the inner areas (Fig. 3), represent regional issues closely connected with regional continuity (extra and intra).

In this sense, the quality of transport infrastructures and services (road, rail, maritime, and air transport) becomes a determining factor in reducing travel times, improving internal connectivity [14, 30], and guaranteeing the right to mobility.

Extra and intra-regional continuity represents one of the main issues for the future of the Sardinia Region, according to the principle of insularity [17] recently established by the new article 119 of the Italian Constitution [2], which represents one of the main results of a growing cultural, social, and political awareness of the peculiarities and diversity of the insular contests [18, 19].

Regional issues and regional disparity are at the core of the e.INS project, which proposes a methodological approach to improve the transport offer to and from Sardinia and within the regional territory by MaaS solutions.

2.2 The Challenges of the e.INS Project – spoke 8

The e.INS project - spoke 8, funded by the Italian Ministry of University and Research under the Next-Generation EU Programme (National Recovery and Resilience Plan (PNRR) [20], is part of the broader technical-scientific debate of sustainable multimodal mobility in the framework of the energy and digital transition, with reference to modal

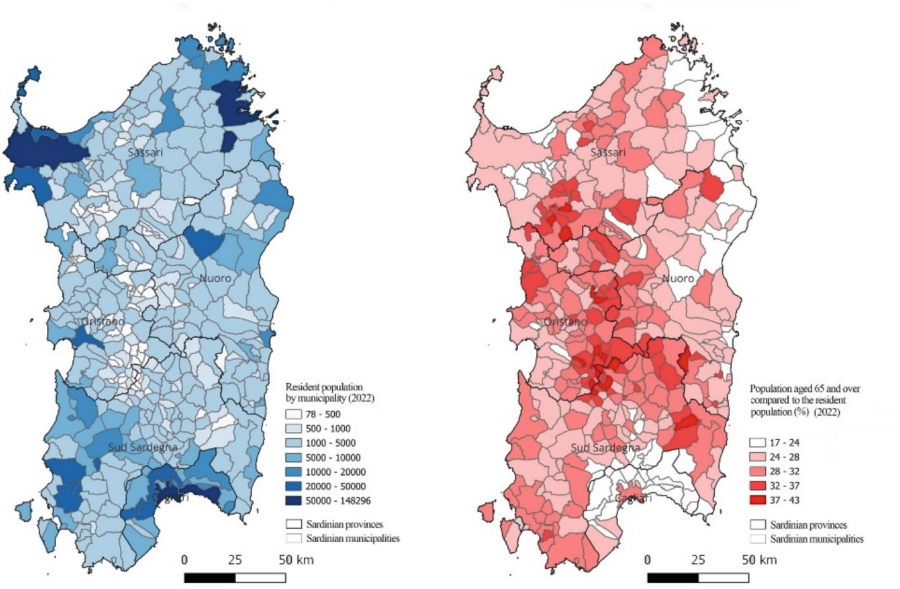


Fig. 3. Resident population by municipalities and percentage of the population aged 65 and over (data source ISTAT). Author: Mara Ladu

integration in the interconnections between Sardinia and the rest of Europe, and within the same regional territory.

In line with the Mobility as a Service (MaaS) perspective [21–24], which will increasingly influence accessibility, mobility and transport, the project evaluates the Sardinia transport system, at different territorial scales (urban, metropolitan, local, and regional) to encourage a modal shift from private cars to more sustainable modes of transport. Particular emphasis is placed on the integration of mobility services, supported by digital platforms for both management and use. A first focus is on accessibility to Sardinia airports, the main passenger gateways to the island. In 2023, passenger movements (arrivals and departures) at Sardinia airports were over 9 million, compared to around 5 million recorded at the ports.

The integration between urban planning, transport systems and ICT represents a prerequisite for a multimodal transport model that combines mobility demand and supply with which to inform a MaaS system. In this perspective the first activity concerns the development of a comprehensive knowledge base of transport demand and supply in Sardinia, which will be used to support the subsequent transport planning and the MaaS solution. More specifically, as summarized in Fig. 4, the research project envisages the following stages, including activities and associated milestones:

– a multi-level geodatabase concerning transport supply (infrastructures capacity, services frequency, and networks coverage), land use structure, provision, and spatial distribution of urban and territorial facilities (Stage I)
– a transport model, i.e. a demand and supply model for sustainable multimodal transport to/from Sardinia's airports (involving local community, city user, tourists), which

also contemplates the seasonal nature of the tourism development model consolidated in the Sardinia Region (Stage II)

– a Mobility as a Service system of the regional transport system to encourage the modal shift from private vehicles to sustainable multimodal mobility options, with particular attention to the promotion of integrated services by a single ticket (Stage III)
– a tool for evaluating the overall impact of the proposed research and a method for transferring the results into practice, making the developed outcomes available to the different target audiences. Evaluation, transfer, and dissemination activities involve private and public subjects to promote a regional sustainable transport planning and an innovative and integrated mobility, especially in the connections between airports and the regional territory (Stage IV).

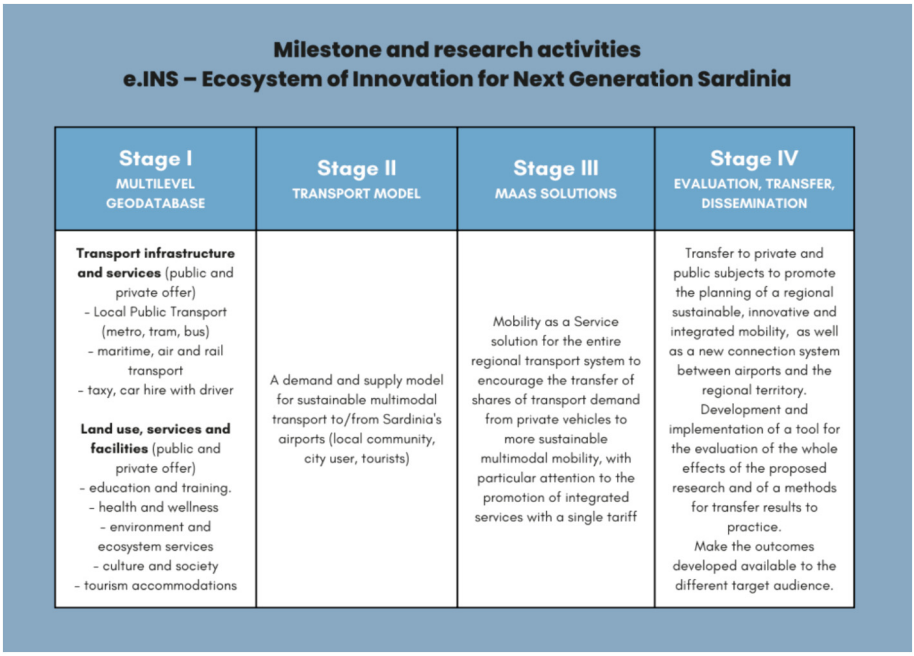


Fig. 4. The e.INS – Ecosystem of Innovation for Next Generation Sardinia project. Milestones and research activities. Author: Mara Ladu

This article describes the first stage of the research.

A methodological approach has been developed for the construction of an open-source multi-level geodatabase (Stage I) to support the development of a demand and supply model for sustainable multimodal transport to and from Sardinia's airports (Stage II), with the aim of creating an airport MaaS solution to meet the needs of residents, tourists, and city users (Stage III). These objectives are in line with the ambition to make the connections between the airport and the tourist destinations more efficient

and sustainable, including consolidated (coastal tourism), and emerging and potential destinations (slow tourism) [25, 31].

The definition of the methodological approach was supported by a theoretical study of the MaaS system from different disciplinary perspectives, aimed at highlighting the multiple aspects to be considered in the development and implementation of the new concept of mobility.

An exploration of enablers and barriers to the implementation of MaaS solutions was carried out to guide the multi-dimensional analysis of the current organization of the regional transport system and to address further integrated policies and interventions aimed at supporting the shift towards the new multimodal transport system. According to the literature, one of the main barriers is the lack of operator commitment and the consequent need to establish effective partnership between the actors involved even with innovations in organizational processes [27, 28].

Closely related to these issues was the analysis of the legal and normative framework with which to approach the design and management of both transport infrastructures (the main Sardinian gateways) and innovative multimodal mobility services, which require cooperation and coordination between all the public and private actors involved, according to their respective roles, competences, and tasks. The in-depth analysis of the legal and regulatory aspects supporting the integration of services and the regulation of the market is a prerequisite to ensure the effective implementation and governance of the MaaS ecosystem in Sardinia.

3 Method

The manuscript proposes a methodological approach to develop a dashboard framework to support MaaS sustainable solutions, according to the eINS project - S poke 8 objectives. More precisely, a multi-level geodatabase (Stage I) is intended to achieve objectives related to the development of a demand and supply model for sustainable multimodal transport to/from Sardinia's airports (local community, city user, tourists), to support the construction of an airport MaaS, of which the conceptual framework is reported (Fig. 5).

Specifically, the construction of the database is divided into the collection and systematization of information (open data) relating to various topics, that characterize the insular socio-economic context of Sardinia. Data has been implemented in accordance with INSPIRE KNOWLEDGE BASE EU Directive (2007) [26]. The standardization structure scheme is as follows: Data (code, name, source), Spatial dimension (unit and global dimension), File (format, date, and frequency update).

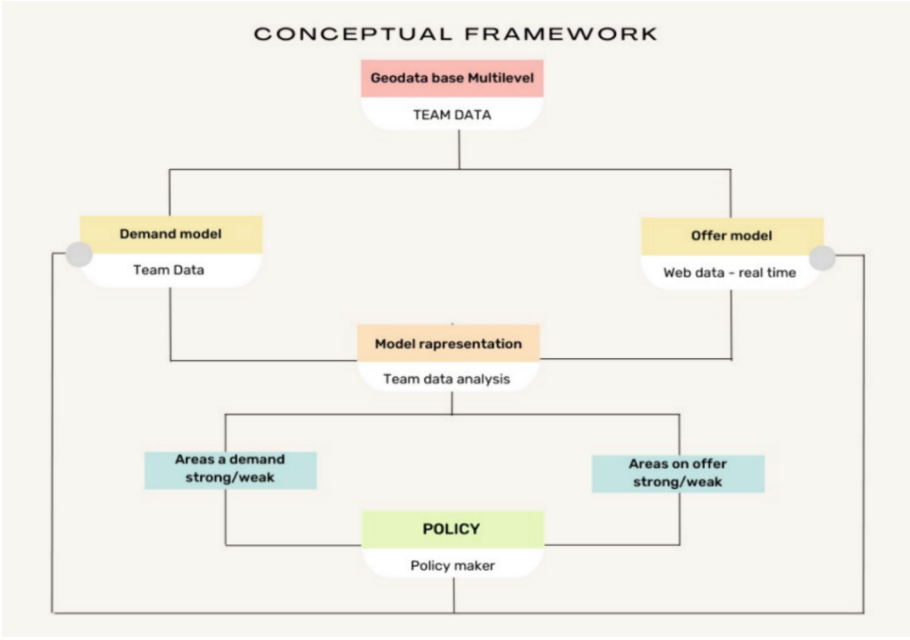


Fig. 5. Dashboard framework to support MaaS sustainable solutions. Author: Ginevra Balletto

4 Results

According to the methodology, a set of data has been implemented and systematized in a multi-level database, preparatory for the construction of a demand (local community and city user) and supply model for sustainable multimodal transport in the island context, to support the construction of MaaS solutions to improve connections to and from Sardinia's airports.

The construction of the Sardinia multi-level geodatabase consists of the collection and systematization of open data (dynamic and static data) relating to various topics, characterizing the insular socio-economic system along with the current provision of infrastructural networks and transport services. The cartographic bases used are: Openstreetmap, Google Earth, MyMaps, etc. with the network of roads, railway and internal maritime routes also represented.

In this section, the main topics selected to develop the multi-level geodatabase (Stage I) are described. Figure 6 shows the main topics selected for the achievement of the targets M001-M004 defined in the project, which concern the construction of a dashboard framework to collect, analyze and monitor the following aspects:

– M001: dynamics of passenger demand to/from Sardinia
– M002: land use (spatial distribution of services and facilities) in Sardinia
– M003: transport system supply to/from Sardinia (extra-regional continuity)
– M004: transport supply in the Sardinia Region (intra-regional continuity).

More precisely the list of the main topics of the collected data for the targets M001 and M002 is reported below:

- Land use: urban services, productive activities, etc.
- Population: population and housing census; Local labor systems; incomes of the population
- Consumption of water and electricity by sector, on a municipal scale
- Production of urban waste, on a municipal scale
- Passenger traffic (air and maritime transport): number of arrivals and departures to and from Sardinian ports and airports
- Tourist movements: number of arrivals and presences, on a municipal scale
- Accommodation facilities: number and type of tourist accommodation facilities, on a municipal scale
- Education. Schools: number and type of schools and number of students, on a municipal scale; University: number of students in Sardinian universities
- Health services: number of hospital beds; type of hospital emergency network structures.

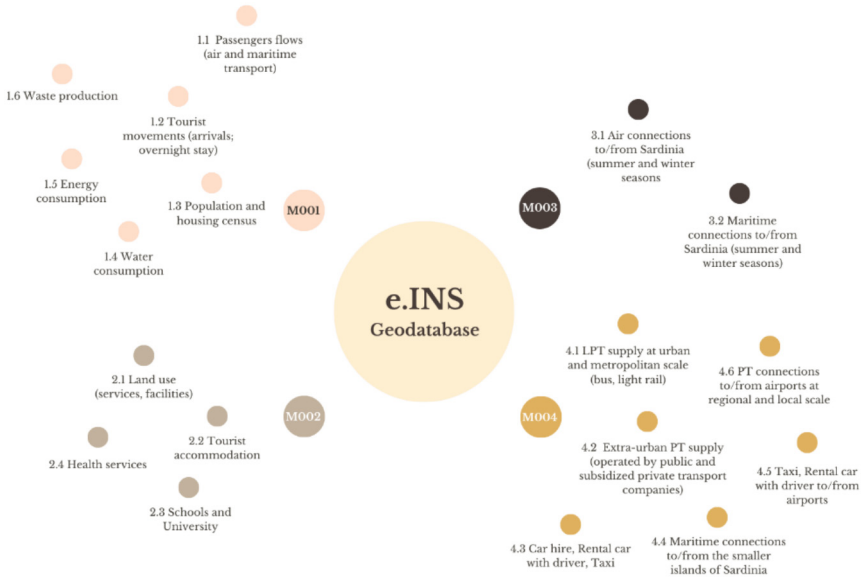


Fig. 6. Framework of the main topics of the multilevel geodatabase. Authors: Ginevra Balletto and Mara Ladu

Target M003 and M004 concern the depiction of the transport supply to and from Sardina and within the island.

The following data were therefore collected and processed to feed the dashboard and develop the transport demand and supply model:

- Data on air and maritime connections to/from the main Sardinian gateways for the whole year

- measurement of the infrastructural network capacity and connectivity
- coverage and frequency of transport services (considering both public and private operators)
- accessibility of the main attractors (transport nodes and urban amenities).

This analysis reveals inequalities between areas in terms of transport provision and, together with the distribution of demand, provides the basis for planning new solutions.

5 Conclusions

Mobility as a Service (MaaS) is an emerging paradigm that offers an alternative to owning a private vehicle. Through a digital platform, users can access a variety of means of transport (individual and collective) by paying only for actual use.

The future of MaaS is full of potential. The evolution of MaaS towards a more integrated, sustainable, and personalized system will have a significant impact on people's lives and on the cities and regions of the future.

MaaS solutions born in metropolitan cities have gradually found application in rural areas, university campuses and large events. Only recently MaaS solutions have been applied in island contexts, Sardinia as a case study.

Insular contexts present specific challenges and opportunities for MaaS implementation. The main challenge derives from the distribution of the population in Sardinia, characterized by a concentration in coastal and urban areas, with a progressive depopulation of inland areas. The aging population and immigration are two factors that influence regional demography.

Sardinia is a tourist destination of primary importance on the international scene, with consolidated attractiveness and constantly growing demand, with the increase in tourist flows (arrivals and presences) representing an opportunity for MaaS solutions.

The multi-level geodatabase is a fundamental component for MaaS solutions. It plays a key role in the formulation and operationalization of innovative and sustainable transport solutions, allows the development of analytical methods and tools with which to detect spatial and temporal disparities and similarities between areas in terms of mobility capital of urban populations (local community, city users as well as tourists) and their corresponding mobility behaviors.

The definition of geographies of accessibility and mobility at regional level is a valuable support for integrated transport and urban planning. It helps to identify low and high demand contexts, reveals travel demand segments and gaps with network coverage and service frequency, highlights inefficiencies.

This context-specific knowledge can support an important innovation process in the organization of mobility and land use in Sardinia. It addresses tailor-made solutions, informs urban policies aimed at balancing territorial relationships and facilitates the establishment of agreements between actors starting with new models of cooperation and partnership in mobility management.

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