Application of Geospatial Analysis to Tourist Flows in the Insular Destinations

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Abstract. Tourism is one of the main growing sectors in the global economy bringing new opportunities associated with the transportation offer. The Covid -19 health crisis, which caused a major shock in tourist flows, also represents the main "*watershed*" for the evaluation of any changes that occurred in the tourism development model and its destinations. In Italy - including the islands - there is a significant recovery in tourist flows post Covid-19. In this framework, the objective of the paper is to develop a methodological approach based on geospatial analysis to evaluate the spatial distribution of tourism flow in Italian insular contexts. In this sense, the Sardinia Region in Italy represents an interesting case study to analyze tourist destinations related to air and maritime traffic (pre and post Covid-19). The manuscript, which is part of the "e.INS – Ecosystem of Innovation for Next Generation Sardinia", supports the construction of the airport MaaS concept, to better organize the transport offer in the insular context, enhancing sustainable mobility.

Keywords: Geospatial Analysis · Tourism Destinations · MaaS

1 Introduction

The European tourism industry is recovering after Covid 19 [1, 2], also due to the increase in passenger traffic, arrivals, and presences [3] - short and long trips - in tourist destinations, diversified experiences and attention to sustainability and technology. Knowing these trends will be critical for destinations to adapt and meet the evolving needs of modern travelers. According to data provided by Enit - National Tourism Agency, with Human Company and Istituto Piepoli, 65% of Italians stay in Italy for their holidays, revealing a predilection for the sea, followed by cultural holidays and stays in the mountains. Digitalization, sustainability, and personalized offerings have become key factors in attracting and retaining customers. Local governments play a crucial role in promoting sustainable tourism by regulating the market for private hospitality homes and improving public transport to increase the accessibility of tourist destinations [4, 5]. In particular, air transport in Italian insular contexts is a growing sector with great potential [6]. However,

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in order to fully exploit this potential, some challenges need to be addressed, such as seasonality in the broader framework of the different models of air territorial continuity [7–9].

The Italian air traffic is exceeding pre-pandemic levels by 11%, thanks to the progressive return to travel for various reasons [10, 11]. The drivers of the great recovery in national air traffic were above all medium and small airports [12], many of which even exceeded 2019 levels. These include the airport system of the Sardinia Region, an Italian island, with the following three airports: Cagliari - Elmas (CAG), Olbia - Costa Smeralda (OLB) and Alghero (AHO), which are the main hubs of the related airport regions (geographical areas characterized by different levels of connectivity with airport infrastructures).

In this framework, the objective of the paper is to develop a methodological approach based on geospatial analysis (Kernel Density Estimations - KDE and Local Indicator Spatial Autocorrelation - LISA) to evaluate the distribution and spatial characteristics of tourism flow in Sardinia Region, highlighting traffic patterns among the local airports and related destinations.

Considering the pandemic as a "watershed" between two moments (pre and post Covid-19), the manuscript analyzes data relating to arrivals, presences, and departures of passengers (short and long trip), in the period between 2019 and 2022 to assess whether elements of continuity or discontinuity can be recorded with respect to the past development trend of the tourism sector.

The results are functional to guide future policies and actions to promote sustainable transport models, especially in connections to and from airports in the regional context, in line with the concept of Mobility as a Service (MaaS) [13].

The manuscript is organized as follows: Sect. 2 - Materials, data and method, provides a description of the study area, the dataset to support geospatial analysis of tourism flows in Sardinia and the methodology; Sect. 3 - Results, discusses the main results of the spatial analytical techniques used to analyze the dynamics of tourist flow; Sect. 4 - Conclusions, proposes possible development in the research field.

2 Materials, Data, and Method

2.1 Study Area

The Sardinia Region, with a surface area of 24,090 km^2, is one of the largest islands in Italy (third in Italy), with a population of 1,578,146 inhabitants (2023) and a population density value of 66 inhabitants/ km^2, among the lowest nationally. The progressive evolution of the administrative geography [14] 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.

The Sardinia Region has a strong tourist vocation, characterized by a marine-seaside tourism model, which reaches its peaks in the summer season, mainly affecting the coastal areas, where 90% of the offer of regional beds is concentrated and the '80% of tourist flows [15]. Seasonal tourism prevails over other forms of tourism. With the Regional Strategic Plan for Tourism (2023–2025) [16], the Region intends to encourage

the digital transition to implement the monitoring activity and enhance the territorial capital in order to diversify the tourist offer [17, 18].

The transport systems in Sardinia consist of [19, 33]: around 9000 km of road network (State and Provincial Roads); 427 km of Italian railway network (RFI) [34], 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; eight ports administered by the Port System Authority of the Sea of Sardinia (Cagliari, Olbia, Porto Torres, Golfo Aranci, Portovesme, Oristano, Santa Teresa di Gallura, Arbatax); three international airports (Cagliari, Olbia, Alghero) which are fundamental for guaranteeing movements (cargo and passenger movements) to and from the Sardinia region (Fig. 1).

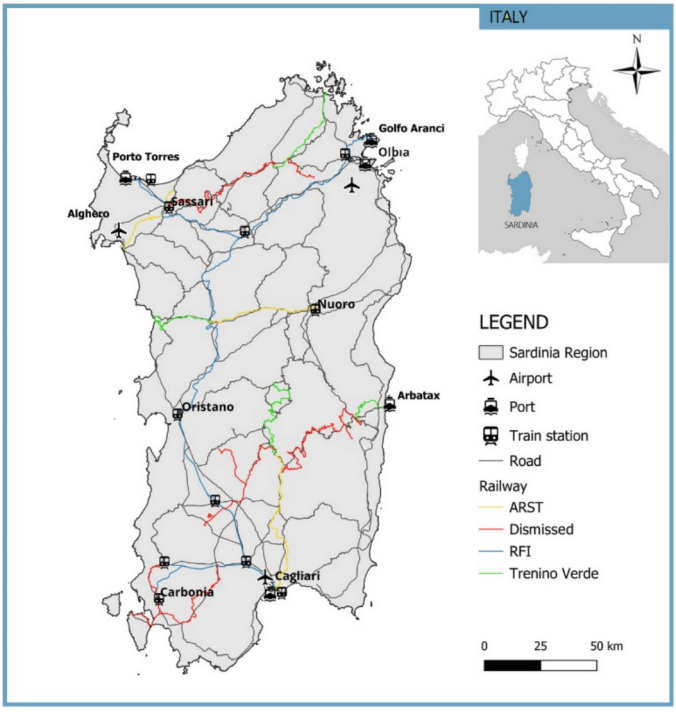

Fig. 1. The regional transport systems in Sardinia (Italy).

However, a substantial gap in the infrastructure system emerges. The poor road and rail accessibility increases the condition of marginality, especially in the internal areas, some of which lack rail connections with the main airports and ports of Sardinia [20]. On the other hand, the private rental and rental with driver (NCC) sectors are growing, helping to rebalance the transport offer in areas with weak demand, guaranteeing connections with the most important centers on the island.

2.2 Data

In line with studies focused on tourist flows and destination management [21–23], the data collected to analyze the spatial distribution of tourist flows in an island context are based on (Table 1):

– n. arrivals and departures (daily, monthly, and annual), from ports and airports
– n. arrivals and presences (monthly and annual), on a municipal basis

Table 1. Dataset to support geospatial analysis of tourism flows in Italy and in the insular case study.

Gateway and Territory	Data	Time	Source (Tourism and Mobility Observatories)	
			Italy	Insular case study
Port	Total arrivals and departures	Year-Month-Day	Italian Ports Association (Assoporti) [26]	Sardinia Region_Sardinia Mobility [24]
Airport	Total arrivals and departures	Year-Month-Day	Italian Airport Association (Assaeroporti) [10]	Sardinia Region_Sardinia Mobility [24]
Tourism destination	Total arrivals and presences (municipality, province, region)	Year-Month	Eurostat [3]	Sardinia Region_Sardinia Tourism [25]
			Banca d'Italia [7]	
			Nomisma [27]	
			USC [11]	

As part of this study, the main open-source data relating to tourist flows in Italy and Sardinia were collected and analyzed. With reference to the latter, the data for the three-year period 2019–2022 can be downloaded in csv format from the main websites of the Sardinia Region:

– arrivals and departures at the island's ports and airports (updated daily) [24].
– arrivals and presences in the municipalities of the island, which inform about how many people arrive each month, where they come from and how long they stay (updated annually) [25].

2.3 Methodology

The proposed methodological approach develops geospatial analysis to evaluate the spatial distribution and patterns of tourism flow in the insular Sardinia Region.

The spatialization of data, i.e. the process of representing and organizing data in relation to physical space, allows you to collect, visualize, analyze, and interpret spatial or geographical data according to their position on the earth's surface.

Geospatial analyzes highlight specific patterns and relationships and correlations between data, producing significant information, also to support sustainable regional planning [28, 29].

The method proposes a double geospatial analysis to evaluate respectively the density of the observed phenomenon (Kernel Density Estimation - KDE) and its spatial autocorrelation (Local Indicator Spatial Autocorrelation - LISA) [30].

The Kernel Density Estimation (KDE) technique is used to analyze the concentration or dispersion of elements in a specific geographic space. The KDE transforms punctual events into a continuous density function distributed in the region of interest, allowing the phenomenon to be represented through a three-dimensional surface that expresses the variation in the density of punctual events in the study area. In fact, KDE uses a three-dimensional kernel function to weight events within a radius of influence (radius parameter or threshold) [31].

The choice of the radius value depends on the nature of the data, the objective of the analysis and the characteristics of the phenomenon studied [5]. A low radius value produces local peaks in the density distribution. On the contrary, a high radius value produces a dilution effect on the observed phenomenon.

Then, the KDE technique identifies the spatial distribution of the studied phenomenon, highlighting regions of high density (clusters) or regions of low density (voids). At the same time, spatial autocorrelation techniques are used to analyze the spatial distribution of objects (whether they are arranged randomly, aggregated, or dispersed in space) and to evaluate the degree of influence and relationship with neighboring elements, i.e. spatial dependence between geographical entities, through various indicators [30].

Moran and Geary's global spatial autocorrelation indicators provide information on the autocorrelation itself, while the localization of high autocorrelation values is provided by local indicators [32], through which the possible presence of clusters or dispersion is highlighted. An example is the Local Indicators of Spatial Association (LISA) index, which evaluates whether a given area of a space has a similar distribution of a variable compared to surrounding areas. LISA is considered as a local Moran indicator, which is directly proportional to the sum of all local indices. The indicator allows, for each location, to evaluate the similarity between each observation and the surrounding elements.

Five cases can occur, in which the different places are characterized by: high values of the phenomenon and high levels of similarity with the neighborhood (high-high); low values of the phenomenon and low levels of similarity with the neighborhood (low-low); high values of the phenomenon and low levels of similarity with the neighborhood (high-low); low values of the phenomenon and high levels of similarity with the neighborhood (low-high); absence of significant autocorrelation.

In this study, the two geospatial analysis techniques are used to evaluate the possible correspondences between the spatial density of the observed phenomenon and its spatial autocorrelation.

3 Results

The study applies the methodological approach in the Sardinia Region, selected as the first study area.

The geospatial analysis of the data relating to arrivals and departures in the ports and airports of the island and the presences recorded in the various municipalities in the period considered (2019–2022), shows a trend of tourist movements to and from the island in constant growth, with the exception of two years (2020 and 2021), when, due to the Covid-19 pandemic, there was a decline in both arrivals and departures compared to previous years.

As regards the data referring to arrivals and departures, in ports and airports, a very similar situation emerges in the years 2019 and 2022 (Fig. 2): the airports of Cagliari and Olbia record a higher number of arrivals and departures than at Alghero airport. Among the ports, the most active one is certainly that of Olbia, recording 1,444,528 arrivals and 1,464,778 departures in 2022.

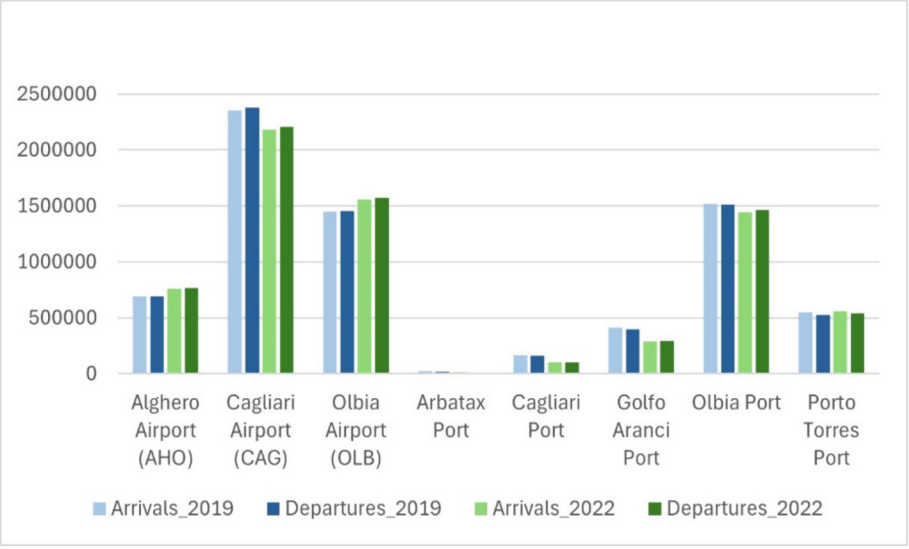

Fig. 2. Arrivals and departures of passengers in the main ports and airports of Sardinia, in the years 2019 and 2022.

The KDE and LISA relating to the number of arrivals and presences recorded in the municipalities of the island highlight the main tourist destinations in relation to the duration of stays (number of days).

The objective of analyzing tourist flows through the KDE technique, with a focus on the municipal scale, required the calculation of the average distance between the centroids of the municipalities of the island to define the size of the radius and, subsequently, the relationship between radius and cell. In the Sardinia Region, this distance is approximately 5 km.

Adopting a radius to cell ratio of 10:1, the KDE was performed by setting a radius of 5 km and the cell of 500 × 500 m. The values chosen for the radius and for the cell allow a representation of the phenomenon excluding the following opposite scenarios [31]: on the one hand, the definition of bandwidth values lower than 500 m, with a spiky representations of the phenomenon, which may provide not much more information on the distribution than the simple observation of the point distribution; on the other hand, the definition of bandwidth values higher than 500 m, with may produce an excessive dilution of the spatial pattern.

The geospatial analysis of presences in the months of August and December produced by KDE does not reveal significant differences between 2019 and 2022 (Fig. 3; Fig. 4). The little difference between the pre- and post-pandemic periods testifies to the rapid recovery of the sector.

Rather, a substantial difference emerges between the winter and summer months, underlining the strong seasonal nature of Sardinia tourism. Furthermore, the presence of regions of high density (clusters) or regions of low density (voids) emerges: the coastal areas are much busier than the more internal areas of the island, with a greater distribution of arrivals near the ports and airports.

Below are the results of the KDE (Fig. 3; Fig. 4) and the LISA method (Fig. 5; Fig. 6) in reference to the data on presences in the months of August (peak month of the summer season) and December, for the years 2019 and 2022.

The results of the KDE analysis confirm several characteristics of the consolidated tourism model in the Sardinia region:

i) a substantial difference in the number of arrivals, departures and presences between the summer and winter seasons, which emphasizes the seasonal nature of Sardinian tourism.
ii) the concentration of arrivals and presences in the coastal areas, which are much more popular than the inland areas (coastal over tourism).
iii) the presence of three main clusters in the month of August, which correspond to the main tourist destinations on the island.
iv) the low attractiveness of inland areas and rural areas, even though they are a privileged destination for other forms of tourism, especially those attributable to slow tourism.

In reference to point iii), the presence of clusters in direct proximity to the urban/port-airport systems of the island (high concentration of tourist movements near the airports), is linked to the significant gaps in the internal connection network, in particular of those to and from the airports/ports, with a consequent increase in the peripherality of some parts of the territory.

The LISA maps for arrivals and presences in the months of August and December for the years 2019 and 2022 (Fig. 5; Fig. 6) reveal a low-low autocorrelation for the internal areas, therefore characterized by a low level of the phenomenon and low levels of similarity. At the same time, the high-high clusters in the main tourist destinations of the island coincide with the results of the KDE, thus confirming the methodological approach.

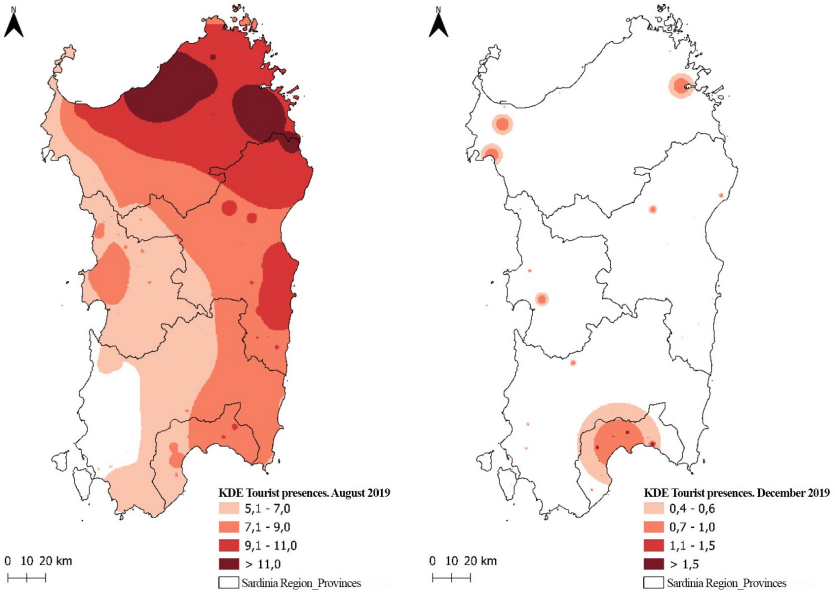

Fig. 3. KDE. Comparison between the spatial distribution of the tourist presences in the Sardinia Region (August 2019; December 2019). R = 5 km, cell of 500 × 500 m.

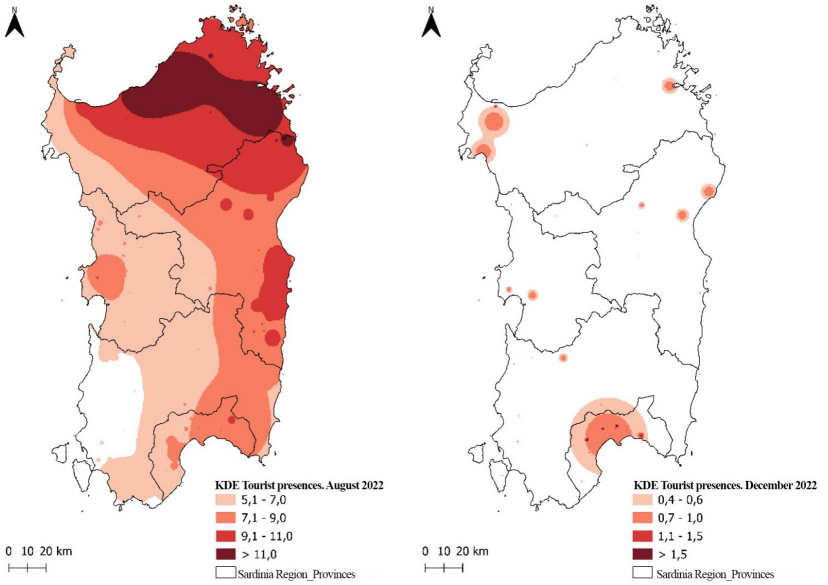

Fig. 4. KDE. Comparison between the spatial distribution of the tourist presences in the Sardinia Region (August 2022; December 2022). R = 5 km, cell of 500 × 500 m.

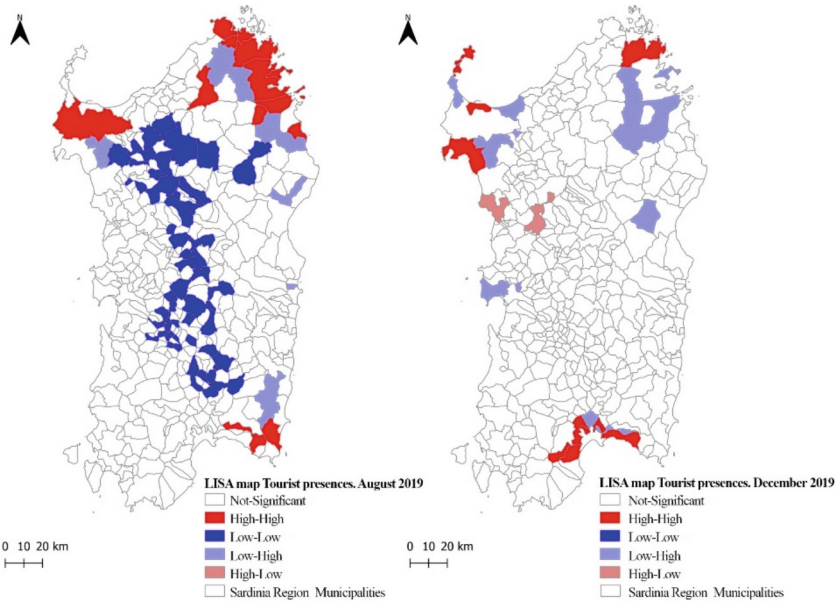

Fig. 5. LISA maps from GeoDa application. Comparison between the spatial distribution of the tourist presences in the Sardinia Region (August 2019; December 2019).

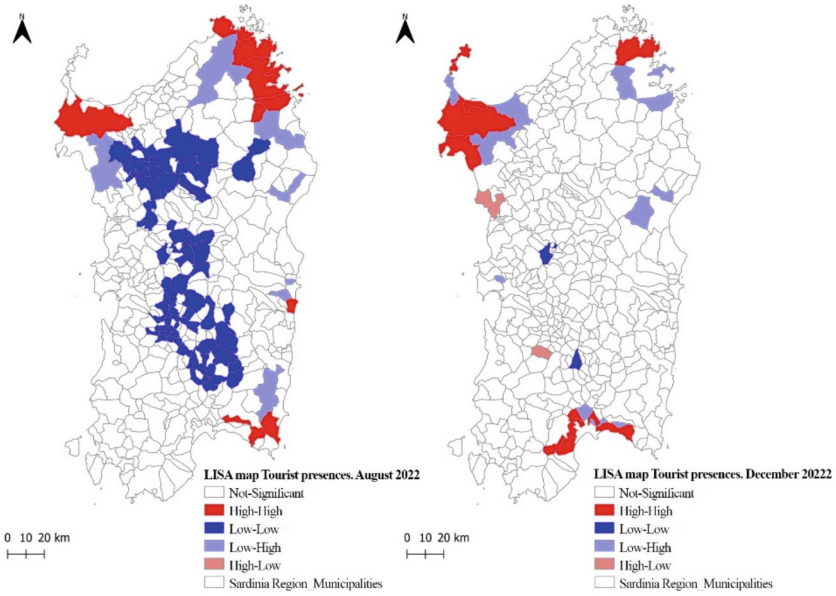

Fig. 6. LISA maps from GeoDa application. Comparison between the spatial distribution of the tourist presences in the Sardinia Region (August 2022; December 2022).

4 Conclusions

The study proposed a methodological approach based on geospatial analysis techniques (KDE and LISA) to analyze the density and spatial autocorrelation of tourist flows in the Sardinia Region in the period 2019–2022.

The geospatial analysis revealed a constant growth trend in arrivals on the island, except in the years 2020 and 2021, in which, due to the Covid-19 pandemic and the consequent limitation of mobility, there was a decline in numbers. The research therefore focused mainly on the years 2019 and 2022 to evaluate if and how the health crisis has influenced tourism development in the Sardinia region. The results of the geospatial analyzes do not reveal differences between the pre-pandemic and post-pandemic periods, which testify to a rapid recovery of the sector. The seasonal nature of Sardinian tourism is confirmed, with significant peaks in the summer months (over tourism), and a distribution of arrivals mostly concentrated along the coasts. At the same time, it was possible to record positive changes in attendance in some internal areas, albeit relatively limited.

Therefore, encouraging the overcoming seasonality and redistribution of tourist movements across the entire regional territory becomes an objective to be pursued also in light of the progressive establishment of slow tourism as an integral part of Sardinia's tourist offer, mainly involving inner and rural areas.

Furthermore, geospatial analyzes show a concentration of the number of presences in an area of approximately one hour from the main ports and airports due to the higher levels of connectivity compared to the rest of the territory, characterized by weak supply and demand for transport. This condition stresses the disadvantages of being an insular context. In this sense, improving transport systems between urban hubs and the main gateways, to ensure effective and sustainable mobility to support tourists and, above all, the resident population, allows the implementation of the main policies developed within the framework of the principle of insularity, recently inserted into the Italian Constitution (art. 119). Furthermore, the presence of clusters of presences in the main tourist destinations of the island recall the need to develop shared policies between the municipalities belonging to the same cluster.

The results obtained support the e.INS project aimed at structuring a sustainable transport offer serving the population and city users, which adequately considers the connections between the road and railway networks and transport hubs in the regional territory, with particular attention to airports and ports, in line with the new perspective of Mobility as a Service (MaaS) and in coherence with the National Airport Plan (2022).

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