Accessibility Improvements and Place-Based Organization in the Island of Sardinia (Italy)

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Abstract. The poor transport system in Sardinia, particularly in the inner areas, affects the social-economic development and the determinants of the productive activities. After illustrating the specificities of these areas in terms of transport accessibility, orography, and the relationship between populations, a new territorial organization is proposed, integrating the new tendencies in mobility. The development of the transport system of these marginal areas plays a key role in future scenarios. In the paper, some analysis highlights the infrastructural weaknesses and the limited accessibility of the inner areas and its negative effects on the local economy. These can be overcome fixing reference hubs, with the function of supplying services and connecting most developed and rich territories located in the coastal areas. On a regional basis, the reference hubs would accomplish the task of a firm, efficient link with the mainland, while the minor hubs would have the function of spreading the urban impact throughout the territory. The strategy matches with the improvement in land accessibility, with vast intervention on the inner road system, and with the creation of a system of strong links with the main urban settlements of the island and with the regional and national transport network. A further strategy is maximizing the integration among infrastructural systems, productive structures, agricultural areas, services, and residential centers, with the perspective of promoting the tourist and environmental vocation of Sardinia. Finally, a new criteria for the infrastructures, integration of the different transport modes with the main transport terminals, is proposed.

Keywords: Accessibility · Place-based organization · Sardinia transport system · Smart and sustainable Island

1 Introduction

In recent decades, urban growth has manifested an important concern, due to the prediction that over 70% of the world's population will live in urban areas by 2050 [1]. In addition, the urban context is characterized by a higher concentration of highly

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qualify human capital is related with positive externalities, such as density efficiency, employment growth, income and innovation [2]. All elements are essential to recognize and spread the urban development and are also functional characteristics of the transport system that support the mobility [3–5], also considering innovative transport systems and technologies to promote sustainable mobility [6, 7]. However, the transport system sector can play a fundamental role in increasing development even in polycentric areas, by implementing the accessibility and mobility between urban and rural areas [8]. In fact, "polycentric development can create critical mass by combining the efforts of urban centres, while delivering more balanced development between regions and more cooperative and functional urban-rural linkages" [9, p. 2]. It is an approach that can enhance accessibility of distant areas and generating opportunities to satisfy people's needs [10]. This process has been highly irregular throughout the Italian territory, mainly influenced by the degree of development of transport [11].

Many areas register depopulation phenomena, and at the same time, the territories are scattered and strongly polycentric with a potential for attraction and resources not expressed. The Technical Committee of the "Inner Areas" of Italian Regions drafted a report relating to the National Strategy of Internal Areas, to develop the local economy through local production chains and supporting primary services to the needs of the population [12]. This document defines a better plan for them by considering multipolar interconnections [13].

In particular, the disadvantage of South's Italy, but also of the major Italian islands (Sicily and Sardinia) is its mountainous territory, and the limited and inadequate transport system [14, 15]. In this regard, according to [16–19] stakeholder engagement in complex transport decisions results fundamental to investigate users' preferences and design new transport services.

Sardinia has the same amount of flat land as the South, but almost two-thirds of its area is on hilly with high altitude, and its altitude distribution is quite unbalanced. Sardinia is also a closed system and for this reason, the mobility sector is easier to study, by considering the different polarities.

The territory organization is not structured as "networks" according to criteria of decentralization and specialization of production and services; these processes are not allowed by the low articulation of the economic structure and related functions that favor the extreme fragmentation in small villages, towns, cities (377 municipalities over 24,100 km^2).

In the past fifty years, the most important in the evolution of Sardinia's economy, the population of the inner areas was characterized by the combined effects of the four following trends, which have weakened the economic-productive structure:

1) a decrease in the population, because of the emigration and the negative balance of demography;
2) population structure and aging;
3) the transfer between population decrease areas and those with an increase, which expand to include the neighborhood centers;
4) a progressive shifting of the population from higher to lower altitudes and coastal areas.

The depopulated territories are nearly always the inner areas of the high hills and mountains, while the growing areas are mostly the coastal areas (tourist economy) and

those immediately gravitating around the industrial poles and principal towns (manufacture and commerce).

Starting from these assumptions, the authors intend to propose some practical suggestions for the infrastructures, by integrating the different transport modes with the main transport terminals. The paper is divided into six sections. Section two presents some reference data of demographic change in Europe and on road network infrastructure. The third section discusses the main objectives for introducing a new Transportation Plan in Sardinia. The fourth and the fifth sections present the results obtained in Sardinia, by considering the accessibility. Finally, the conclusions section summarises the fundamental findings of the study, by underlining the implications of the research, and by giving practical suggestions for their implementation.

2 Some Reference Data on Demographic Changes and on Road Network Infrastructure

Demographic changes have various consequences for European territories [20]. Rural and inland areas are experiencing a significant population decline, exacerbating the economic decline. This situation, common in Europe, is a problem faced by the regions and which unfortunately increases the gap between rural and urban areas and affects the social, economic, and territorial cohesion of the EU. Figure 1 shows the average annual population change.

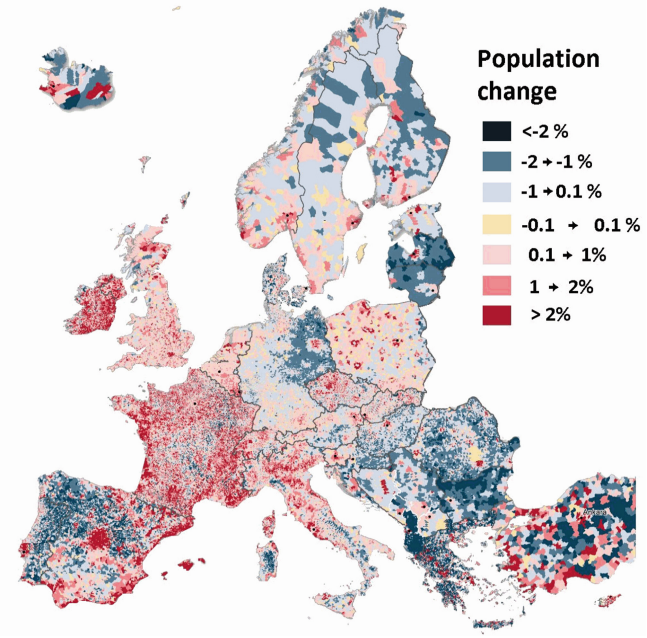

Fig. 1. The average annual population change in Europe 2019 [20].

However, at the same time, the high concentration of people in urban metropolitan hubs creates many negative consequences, such as pollution, life quality, road congestion, the impact on the pre-existing natural environment, and the tragic road accidents [21]. The mobility phenomenon means also to observe circulation as it appears exteriorly, by identifying the diverse and multiple economic and existential causes of mobility. The first two factors to be considered are 1) the capabilities of the available infrastructural systems, and 2) the correct use of resource-saving technologies.

Italy has a road network infrastructure of about 492,000 km with a territorial density of about 1.63 km/km^2, which is more than the European average (1.23 km/km^2) though it has a higher vehicle density, about 78 vehicles per km, compared to the 53 vehicles per km in Europe e and the 28 vehicles per km of the USA [15, 22]. An immediate consideration is that Italy needs a different distribution of passenger and goods transport without necessarily having to develop, rather than adapt, the Italian road network in order to develop road transport. Figure 2 shows the distribution of the total road network in Europe and Italian regions, underlining the actual situation (the region of Sardina is in black).

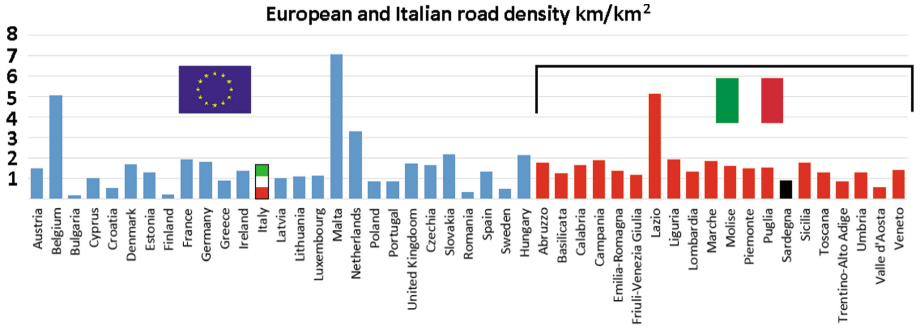

Fig. 2. Density of the total road network in Europe and Italian regions (km/km^2) (Graph based on available data in [15, 20]

In addition, about the 50% of the ordinary roads shows clear signs of a need to be adapted to conform to new design criteria, and those more dangerous accidents have been found to happen on ordinary roads [15]. The 50% of the Italian roads defined "mediocre" are in the South and islands and these roads represent only a third of the total road network. Nevertheless, only 2‰ of the total economic resources were allotted for maintenance. In a nutshell, protection of the present state of the asset is an important priority. It is also important to underline that the expansion of the infrastructural communication network (particularly in the Sardinian road network) has not responded to the different territorial needs. The new roads were often a consequence of the sectorial needs and demands, rather than as a result of a general regional plan.

There is an absolute necessity of rationalizing the system of transport infrastructures that should be adapted to the socio-economic reality of the territory and its development corridors [23, 24], in order to ensure adequate traffic conditions, limiting

congestion and saturation of road capacity and ensuring adequate travel time reliability of transport services [25–27]. All this, however, respecting, safeguarding and valorizing particular historical-environmental features, promoting and guaranteeing conditions of widespread accessibility and paying attention to all mobility levels [28–30] as well as agreeing with complex economic planning.

Over time, the Italian regional and local administrations have prepared many General and Provincial Transportation Plans. These plans contain a preliminary knowledge of the general characteristics of the land, populations, economic and service activities, the transport system and in particular of the road network.

In Sardinia the main regional tool of transportation and transport system is the General Transportation Plan (approved by Regional Government in 2008) and its main objective is a comprehensive transportation system oriented towards sustainable forms of transport, the shortcomings of which have contributed to the success of road transport.

However, in a society characterized by ever-increasing mobility, the road network is one of the weak links in the productive chain of the island of Sardinia and damage the competitiveness of the local enterprise and the social texture of the territory.

Considering the existing situations, plan, programs, choices, objectives, and to the general lines of the planning tools, the authors propose the following suggestions:

a) adaptation and restructuring of the transportation system;
b) creation or transformation of new sustainable communication infrastructures.

The principal objective in planning the transport system, and in particular the road network, is that of reducing the economic cost of transport, and of improving the serviceability and safety of the road network so as to increase land accessibility.

These premises serve to understand the needs and objectives to be pursued in redesigning the transport system, especially considering the Sardinian case study.

3 Objectives for a New Sardinia Transportation Plan Considering the Road Network

In general, the General Transportation Plan deals with different aspects: mobility of people, the generalized cost of transport, the reduction of impacts on the environment and the increase in job opportunities.

However, the authors in this paper deal only with the road sector, by analyzing how it can change social and economic structures.

The objectives of the transport system in Sardinia must be based on the consideration that its territory is characterized by a marked organization of “poles” of productive activity and services. The indications that could be reached, therefore, regard communication infrastructures not strictly referred to provincial territories of competence. In areas of a low settlement density, the availability of jobs, of social and cultural exchange of a higher level, and access to services on a regional scale, is almost always concentrated in a few “poles”. On the one hand, this situation of unbalance is the main reason for trips towards “strong” areas, and on the other, it is difficult to change except at the price of oversizing some of the services, thus supporting diseconomies. Thus, the

accessibility in certain areas is made possible and therefore facilitated through the creation of opportunities for enjoyment, economic and socio-cultural activities that tend to be located in specific areas. So, the presence of an adequate transport system causes structural conditions for the creation of a more homogeneous territorial distribution of employment and service opportunities.

The main objective in the transportation planning of the various territorial systems is to design an organic transport system capable of creating conditions of accessibility in the function of improving the economic conditions and the general living conditions of its inhabitants.

The Sardinia Transportation Plan identifies eight prevalent gravitation centers. Therefore, the authors with the found data and information, intend to determine whether the same territorial organization is to be confirmed in the future or whether, without prejudice to the functions localized in these centers, a role could realistically be found in the provincial and regional territory. This hub can be a gravitational point for other centers with a district effect concerning education, health and other services of an administrative nature. The main issue is understanding the correspondence between the existing road network and the demand generated by i) present and future forms of settlement; ii) changes in the productive organization; iii) the necessity of guaranteeing adequate road support to tourism, for example. The intervention on the road network is not neutral for the structure of the phenomena that it meets.

The dislocation of settlements (human, productive, and services), the mobility system, and the general function of an area are strongly conditioned by the type of internal and external road structures that support them.

The processes of population concentration, abandonment of inner areas and development of tourist activities will extend to the whole of the next decade: Sardinia is still in the early phases of industrialization, where according to a behavior model observed in other regions, economic development accompanies processes of territorial concentration. The Sardinia economic development will be characterized by the same trend as in the past and dragged by the development of already formed "strong" areas is forecast. The demand for land accessibility derives from the people mobility the needs of the productive world. Tue external road structures can support all of this.

A significant consideration is to be given to: i) demographic evolution; ii) demand and supply of access to primary and specialized services; iii) the accessibility opportunity of the territory and iv) development of economic resources, by considering also the protection of areas with environmental and landscape value.

These different requirements express the general need for requalification and re-equilibrium in the utilization of the resources of a territory where a few "strong" areas tend to affect the development of surrounding areas, and therefore where the opposition between "poles of development" and deep layers of emarginated territory prevails. The strategic objective proposed in planning a new transport system is a land re-equilibrium, that recognizes the high-risk level deriving from the abandonment and marginalization of large portions of territory. Moreover, it should be rearranged and rationalize the "strong" axes network and the "poles," but that should also contribute to reconstruct and reinforce the weak areas, by considering planning tools, urban and transport processes and strategic spatial planning [31–33].

Obviously, a simple intervention on the road system is not able to manage and solve rebalancing problems. The possible solutions are combined with adequate land policies and real activities i) for the location of civil services, business services and production and ii) for the environment and urban planning in general. However, a set of capillary works on the internal road network and a robust connection system with the main urban settlements may play a fundamental role in the re-utilization of these territories and their recovery towards economic development based on the valorization of natural, cultural, handicraft and agricultural resources.

Authors suggest the following activities to bring into consideration:

- the removal of the severe difficulties experienced by these areas in the utilization of the primary social and economic services concentrated in a small number of "poles";
- the creation of efficient intermediate hubs capable of determining a road structure that works as a frame of reference for the minor settlements as an alternative to the Provinces;
- the creation of a network of tourist itineraries involving not only to the main tourist areas but also the surrounding ones with minor cultural goods, in order to support the unique local environmental and cultural resources.

But before showing the results of the research in detail, it is important to frame the concept of accessibility and how this concept can be applied for Sardinia.

4 Land Accessibility: The Case Study of Sardinia

The term accessibility, intended as "facility of access" to a specific place, is define as the measure "to which land-use and transport systems enable groups of individuals to reach activities or destinations by means of a combination of transport modes" [34, p. 115]. The accessibility does not consider the presence in the neighborhood of residences, services or workplaces convenient for facilitating access in order to satisfy a concrete trip demand.

A different interpretation of accessibility is not necessary for the traditional procedure for the transport system layout. The sizing and choice of transport alternatives follow the analysis and forecast of the demand for mobility and, after adequate consideration of both demand and supply, the accessibility can be guaranteed to the users who wish to go from a point A to a Point B or to different centers. In this way, if the demand is either impossible or difficult to quantify, a reasoned choice of works on the transport system is prevented. The actual system imposes to proceed following a general logic (of guaranteeing communication among all centers, functionally distinguishing ways of communication, adjusting the characteristics of the infrastructures along main itineraries, and so on).

In Sardinia, this logic is applied through the analysis on the 377 municipalities of the travel times allowed by the current road network. The area that can be reached at a certain moment increases as the movement is greater and less expensive.

Two distinct cases are represented in Fig. 3: Cagliari is on the plain and has many highways with few curves and high travel speeds. Seui is in the mountains and has a

narrow winding road with very low speeds. In the first case, the area that can be reached in an hour (within the blue area) is much larger. Furthermore, Seui is in a much more central position, but has longer travel times to more distant centers (more intense red areas) and for large portions of territory (larger red surface).

The direct distance from coastal areas to Seui is only 30.5 km, but the real road distance is 75 km traveled in 1 ^{h}.30 ^{m}. Seui registers in the last decade a depopulation of 11.69% and, at the same time Tortolì (the closest coastal center) increase of 3.1% their population.

Infrastructural support appears very inadequate to sustain the socio-economic development trends of the different regions of Sardinia. Generally, the elaborated analyses shows that land accessibility, and, therefore, the quality of life are compromised not only by the lack of appropriate infrastructures but also by the geometric and layout characteristics of the road network.

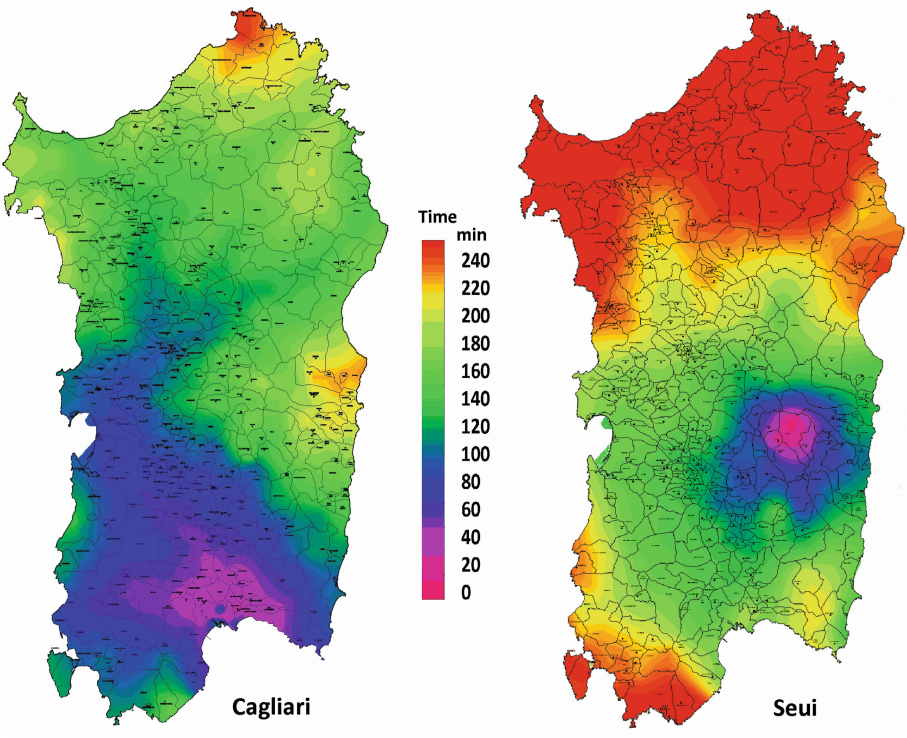

Fig. 3. The isochronous distribution comparison: Cagliari is the main municipality in Sardinia (on the left) on the south coast; Seui is a small village (on the right).

Distance in traveling time is judged as the most representative parameter to describe the state of road accessibility and Fig. 4 shows la distribution of time for five different situations.

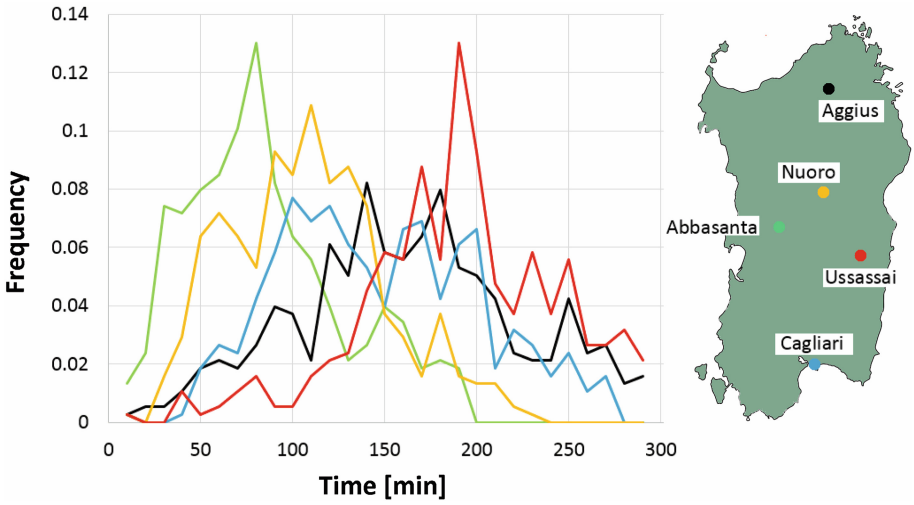

Fig. 4. The distribution of time from one municipality and the other 376 ones.

Furthermore, Fig. 5 shows the distribution of the average time to reach the other 376 municipalities. Namely, the municipality located in the blue area has excellent accessibility conditions unlike those in the red area. The commercial speeds on the whole road network as a function of the geometric and layout characteristics and the entity of traffic flow were measured preliminarily. The distances in traveling time for each provincial territory and the whole regional territory were measured for the primarily residential, productive, and services settlements and to other hubs that may be defined as having a "pole function", such that they can be assigned land re-equilibrium functions.

The following municipalities are considered as hubs:

- Metropolitan City of Cagliari: Cagliari;
- Province of South Sardinia: Carbonia, Dolianova, Guspini, Iglesias, Muravera, San Gavino, Sanluri, Sant'Andrea Frius, Sant'Antioco, Senorbì, Silius, Villacidro, and Villasor;
- Province of Nuoro: Nuoro, Bosa, Isili, Lanusei, Macomer, Siniscola, Sorgono, and Tortolì;
- Province of Oristano: Oristano, Abbasanta/Ghilarza, Ales, Arborea, Cuglieri, Samugheo, and Santulussurgiu;
- province of Sassari: Sassari, Alghero, Olbia, Ozieri, Portotorres, and Tempio.

As residential, productive, and services settlements and external transport hubs at the regional level, following municipalities are considered: Cagliari, Iglesias, Macomer, Nuoro, Olbia (for Olbia and Golfo Aranci), Oristano, Sassari (for Alghero, Portotorres and Sassari) and Tortolì. The analysis shows the deficiencies of the road network in the different regions of the provincial and regional territory. Accessibility

conditions depend on the quality of the geometric and layout characteristics, and therefore on the serviceability levels of the road networks of the different regions.

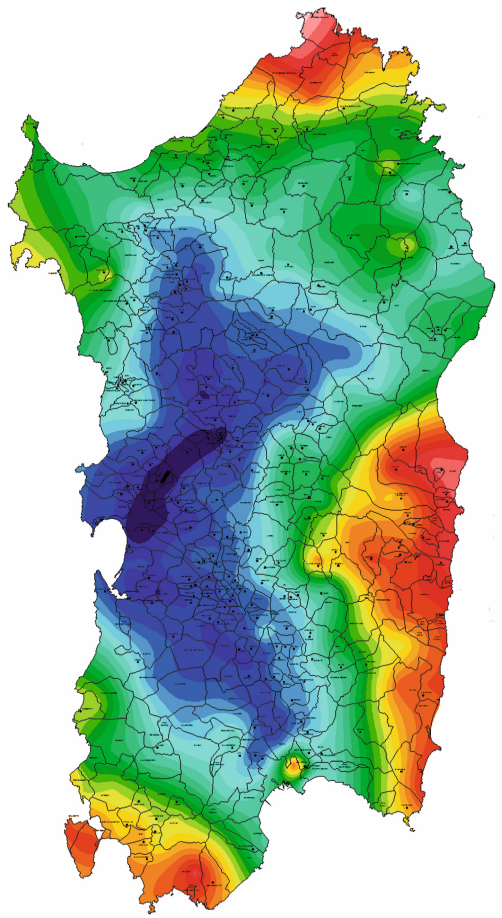

Fig. 5. The distribution of average time to reach the other 376 municipalities.

Particularly deficient are the road networks serving the Flumini region (between Iglesias and Guspini) and the Sarrabus-Gerrei region in the province of South Sardegna; the Barbagia d'Ogliastra and the Barbagia of Sarcidano regions in the province of Nuoro; in the regions in the province of Oristano with Ales, Cuglieri, Samugheo and Santulussurgiu as "hubs" of reference; and in Anglona, Goceano and mountain Gallura in the province of Sassari. Land accessibility is different and better in areas served by "type A - particular destination" roads such as the S.S. 131 - 131 DCN main roads, or roads serving the Industrial Development Areas and Industrialisation Nuclei.

To those factors, it is also necessary to consider also the correlation between depopulation and accessibility. For the region of Sardinia, this correlation is significant, equal to 0.696 using an exponential trend line (Fig. 6).

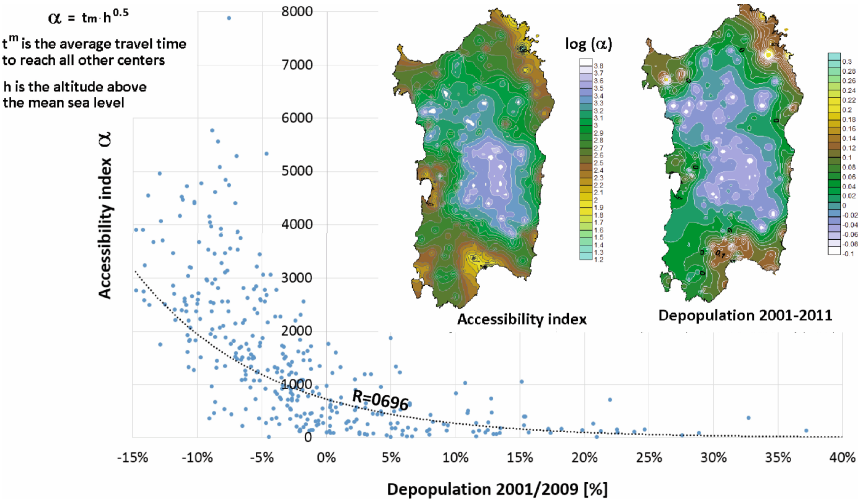

Fig. 6. A good correlation (R = 0.696) was found between depopulation and accessibility index

5 Results: Proposal of a Method of Intervention for the Insular Context of Sardinia

The analyses proposed on the transport system in Sardinia have shown that, according to technical characteristics, internal and external relations impose a general adjustment of the communication infrastructures, mainly through an improvement of the layout characteristics.

Historically, the study of the growth dynamics of many economic systems has shown that investments in the transportation sector often are a decisive factor in the formation of capital. In the south of Italy and islands, despite many works had been guided, often they remain unfinished for decades. The conclusion is that investment in transport represents a necessary, though not sufficient, condition for the development of a specific geographic area. A critical structural transformations is needed in order to create, or change, the transport network, but it is necessary a good coordination for investments aimed at stimulating growth.

A consequence of this approach is that specific traditional procedures aimed at assessing the appropriateness of investment projects, for example, in the road sector, do not respond to the objective of promoting balanced growth. On the contrary, in some cases, the creation of large-scale works were done, using resources that could have been invested in more urgent projects for development.

Therefore, it is important to abandon the purely sectorial vision of the problem of road planning and transport planning in general; this could only be done by introducing what we can call "development benefits" in the analysis.

This category of benefits should be determined as the result of global investment, or better, of the entire productive effort, and not as an effect of partial investments, such as roads. From these brief remarks, it emerges that the planning and layout of transport systems must no longer (or better not only) be confronted sectorial, but in the general view of the process of economic development within which the works are done. The layout of a road or a railway does not have a separate configuration but is an integral part of land planning.

Each transport component plays a role corresponding to its own technical and economic peculiarities, and all the components, organized hierarchically, concur to define the territorial layout that is functional to the pre-established socioeconomic layout. All this determines the mobility of people and is fundamental for understanding the processes underway. Figure 7 shows some characteristics in terms of attracted and generated trips.

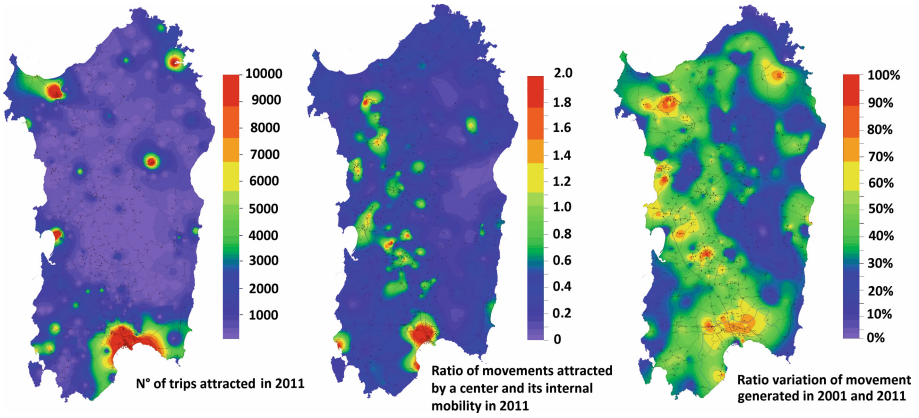

Fig. 7. Some characteristics of mobility in Sardinia: the number of total trips attracted by each hub (on the left), the ratio of trips attracted by a hub and its internal mobility and, variation of movements between 2001 and 2011 (on the right).

Another inspiring concept is that the transport system must be used to control the localization of activities on the territory, which is the crucial point not only of town-planning and territorial problems but also of traffic and circulation problems. In order to assess the territorial layout that can be associated with intervention in transport, connectivity is of fundamental importance, at least for the following reasons:

- the increase in the connectivity of the transport network is the fundamental condition for supporting the formation of a more territorial network structure, in view of a better extension of development;

- some of the main impediments and constraints to the extension of development are related to variations in connectivity due to the unequal development of transport.

The layout of a transportation system should be founded on the following main options:

- an adequate exploration of the possibilities of requalifying the intercity road communication network with investments aimed at relieving congested areas by offering a better distribution of the values of accessibility and connectivity;
- a check of the hypotheses of improvement of the connection between minor urban systems and "strong" areas, through efficient local transport services in terms of service reliability and intensity.

Considering the organization of urban areas, the authors suggest the following guidelines:

- a detailed study of the possibility of promoting the mobility shift from private to public transport, while checking the attainable thresholds and town-planning implications;
- an exploration of the possibilities and implications of organization strategies of the primary railway hubs serving regional and metropolitan mobility, both in terms of the distribution of accessibility values that could promote evolution towards a net structure of settlement patterns, and in terms of management models;
- an integrated holistic approach that brings people's needs back to the center of projects [35].

Finally, productive sectors require a transport system that should respond to high levels of efficiency, safety, and speed, in order to operate efficiently and in a competitive way. Occasional, spontaneous, partial responses to such needs have not led to a transportation system with modern, technological, and organizational characteristics so far, and are very unlikely to do so in the future. The crucial intervention in the sector, relating to both the functioning, reorganization, and renewal of the existing transport supply as well as improving it, should be planned, defined, and proposed according to a new way of organizing the system of decisions in transport.

This allows that intervention and the corresponding expense a) are consistent at all levels, b) concern expense needs arising from reliable forecasts of demands of a growing economic system, and c) are done most opportunely according to a scheme of priorities. Unacceptable expense delays or useless anticipations are avoid, by integrating among different modes, by globalizing the expense wasted today, and by optimizing the resources. The choice of priorities must occur, therefore, based on a uniform method that can examine not only economic but also social and environmental aspects.

6 Conclusions and Remarks

The paper presented wanted to underline how the traditional planning and design procedures don't work if in the preparation of plans for areas of a low population density is partially characterized by the presence of medium-large urban

concentrations. In fact, in such a case, also owing to insufficiently defined scenarios of socio-economic development, the future demand for transport is not easily foreseen and for this reason, sizing a communication system can be a challenging task.

It is, therefore, not the entity of the demand, that may be binding for choices, but more articulated considerations related to the level of the quality of life, the safety and care of the territory, the environmental protection and enhancing local products and culture.

An essential component is the availability of job opportunities, higher-level services, and the possibility of social relationships. It is clear the importance of connecting the inner areas to coastal ones, where commerce and tourism offer jobs, better incomes, services, and social relationships.

In order to make the "poles" entirely available for the population of marginal areas, it is essential to make them accessible, that is, to make the trip to reach them cheap, fast, safe, and comfortable. Namely, it is crucial to improve their accessibility. Accessibility and quality of life thus establish an inseparable couple in low population density areas: accessibility may become reliable support in the definition of priorities of intervention on the transport system.

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