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Computational Science and Its Applications – ICCSA 2020

20th International Conference
Cagliari, Italy, July 1–4, 2020
Proceedings, Part VII

Part VII

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Preface

These seven volumes (LNCS volumes 12249–12255) consist of the peer-reviewed papers from the International Conference on Computational Science and Its Applications (ICCSA 2020) which took place from July 1–4, 2020. Initially the conference was planned to be held in Cagliari, Italy, in collaboration with the University of Cagliari, but due to the COVID-19 pandemic it was organized as an online event.

ICCSA 2020 was a successful event in the conference series, previously held in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing, China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies. The ICCSA conference series has provided a venue for researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in computational science.

Apart from the general track, ICCSA 2020 also included 52 workshops in various areas of computational science, ranging from computational science technologies to specific areas of computational science, such as software engineering, security, machine learning and artificial intelligence, blockchain technologies, and of applications in many fields. We accepted 498 papers, distributed among 6 conference main tracks, which included 52 in workshops and 32 short papers. We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2020 in particular, vitaly depends on the support from many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, Organizing Committee members, student volunteers, Program Committee members, Advisory Committee members, international liaison chairs, reviewers, and others in various roles. We take this opportunity to wholeheartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the Best Papers Awards, and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website http://www.iccsa.org where you can find all the relevant information about this interesting and exciting event.

July 2020

Osvaldo Gervasi
Beniamino Murgante
Sanjay Misra

Welcome to the Online Conference

The COVID-19 pandemic disrupted our plans for ICCSA 2020, as was the case for the scientific community around the world. Hence, we had to promptly regroup and rush to set in place the organization and the underlying infrastructure of the online event.

We chose to build the technological infrastructure using only open source software. In particular, we used Jitsi (`jitsi.org`) for the videoconferencing, Riot (`riot.im`) together with Matrix (`matrix.org`) for chat and asynchronous communication, and Jibri (`github.com/jitsi/jibri`) for live streaming sessions on YouTube.

Six Jitsi servers were set up, one for each parallel session. The participants of the sessions were helped and assisted by eight volunteer students (from the Universities of Cagliari, Florence, Perugia, and Bari), who assured technical support and smooth running of the conference proceedings.

The implementation of the software infrastructure and the technical coordination of the volunteers was carried out by Damiano Perri and Marco Simonetti.

Our warmest thanks go to all the volunteering students, to the technical coordinators, and to the development communities of Jitsi, Jibri, Riot, and Matrix, who made their terrific platforms available as open source software.

Our heartfelt thanks go to the keynote speakers: Yaneer Bar-Yam, Cecilia Ceccarelli, and Vincenzo Piuri and to the guests of the closing keynote panel: Mike Batty, Denise Pumain, and Alexis Tsoukiàs.

A big thank you goes to all the 454 speakers, many of whom showed an enormous collaborative spirit, sometimes participating and presenting in almost prohibitive times of the day, given that the participants of this year's conference come from 52 countries scattered over many time zones of the globe.

Finally, we would like to thank Google for letting us livestream all the events via YouTube. In addition to lightening the load of our Jitsi servers, that will allow us to keep memory and to be able to review the most exciting moments of the conference.

We all hope to meet in our beautiful Cagliari next year, safe from COVID-19, and finally free to meet in person and enjoy the beauty of the ICCSA community in the enchanting Sardinia.

July 2020

Ivan Blečić
Chiara Garau

Organization

ICCSA 2020 was organized by the University of Cagliari (Italy), University of Perugia (Italy), University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), and University of Minho (Portugal).

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Reticular Systems to Identify Aggregation and Attraction Potentials in Island Contexts. The Case Study of Sardinia (Italy)

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Abstract. The purpose of the article is to evaluate territorial hierarchies, internal to an island context, through the theory of central places. To this end, the authors want to demonstrate how some key points of these theories are still relevant all the more if applied to geographically closed contexts, such as an island. Starting from these premises, this paper begins with a literature revision on the most important theories on central places with particular reference to the theories closest to contemporary world. Therefore, the authors study the attraction and aggregation potential of the Sardinian case study, defined by the most suitable localization theories for studying island contexts. This allowed not only to study the analysis of flows through a territorial-hierarchical model, under the theoretical assumptions of the Central Places Theories (CPTs), but also to develop a model and a reticular system on several levels, starting from the population data. This paper shows a first phase of a wider research and provides a bibliographic framework to understand how the theories of central places are still suitable for studying a closed system like an island.

Keywords: Central Places Theories · Reticular system · Analysis of flows · Territorial-hierarchical model · Smart island · Sardinia

1 Introduction

Nowadays, the urbanization process is increasing significantly, by changing the size and the spatial distribution of population in cities and, for that reason, outlining a clear distinction between major and minor polarities [1], in which the irregular development of the territory is evident especially in geographically closed contexts such as islands. In fact, the islands are characterized by an irregular urban structure that presents in the coastal areas the hubs of major urban, economic and social development and the

This paper is the result of the joint work of the authors. In particular, paragraphs 3, and 4 have been jointly written by all authors. Giulia Desogus has written paragraph 1. Chiara Garau has written paragraph 2. Pasquale Mistretta has written paragraph 5.

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centers with the least progress in the internal areas. This topic related to the study of the central theories has a long history and among the different models that have attempted to describe the evolution of an urban structure, that one of Christaller [2–5] (with the appropriate precautions in relation to the contemporaneity of tools and of data analysis) remains the most authoritative one. The authors therefore considered appropriate to conduct a comparative study of the evolution of central places theories, starting from the theoretical apparatus, to then deepen the analysis on island contexts, where, for obvious geomorphological reasons, the problem appears more evident. In this regard, before tackling the aforementioned historical excursus, it is fundamental to understand what is meant by an insular context. The European Union defines an island as a system surrounded by the sea which must be "a minimum surface of 1 km^2, a minimum distance between the island and the mainland of 1 km, a resident population of more than 50 inhabitants, no fixed link (for example, a bridge, a tunnel, or a dyke) between the island(s) and the mainland" [6]. This identifies the island with a precise border within which there is its own geographical and urban structure. This typicality leads to reasoning on two issues that by definition are common to all the islands. The first issue concerns the structural problems typical of an island context [7, 8]. As the European Union argues, all island regions have the problem of insularity facing much greater difficulties in achieving an average level of socio-economic development in the European Union [8–11]. The second issue concerns the lack of homogeneity between coastal and inland areas, even more evident in an island context [12–14], especially in those contexts in which (as in Sicily and Sardinia for Italy) the same islands are considered for their development, comparable as extension to non-island regions.

These aspects of insularity are strongly linked not only to the functionality of urban settlements, but also to their interconnections within the island and to the urban effect derived from the concentration and location of activities in the area.

These reasons lead the authors to reflect on smart governance capable of balancing this closed system, with problems related to insularity and lack of place-based homogeneity. In particular, the authors consider those contexts within the islands, subject to a gravitational dynamic with respect to the different (large, medium and small) centralities, by identifying as internal areas "a network of municipalities or groups of municipalities […] around which gravitate areas characterized by different levels of the spatial periphery" [15: 1].

The central places theory (CPT) with its subsequent evolutions and proper integrations will be presented in the following paragraph and it appears to be the most significant theory to analyze this, because the theme of island development, especially in terms of smart urban planning in a regional geographical area, must be developed through synthesis of organizational mechanisms between major cities, suburbs, inland areas and rural areas [16, 17]. Subsequently, the theoretical apparatus will be applied to the island context of Sardinia (Italy). Sardinia appears to be a significant case study, because its geographic extension and conformation allows the territory to be divided into subsystems with which the large gap between inland and coastal areas can be analyzed.

This research makes possible to identify urban strategic polarities not only for having a new and widespread awareness of the internal areas of the island contexts, but also for developing and better planning a complete framework, by considering all multipolar interconnections of the considered island.

2 State of the Art on Regional and Urban Growth: Central Places Theories and its Evolution

The central places theories (CPTs) appear to be applied in its beginnings, mainly to economic geography and, although they were applied to contexts far from the contemporary, it seems useful to make a historical excursus to trace the theories still applicable and effective today. Over the course of time, these theories have dealt with how territorial features changed, analyzing in detail how territorial imbalances are produced as a result of central hubs [18].

The most important and pioneering theoretical insights about the central places theories - aimed at an analysis of urban systems with correlations on regional growth - were provided by Weber (1909) with his classical theory of industrial location [19]; by Christaller [20] with its theory of central places; by Zipf with his rank-size rule [21].

The basic element constituted by Christaller's theory considers the city (in its tertiary function as producer of service goods) as the central point of the territory and it influences its nearby cities and the number of inhabitants distributed in the territory. The areas of influence, associated with the tertiary functions, overlap each other, creating interrelated regions (nodal regions) determining urban systems consisting of agglomerations and dominant centers or dominated areas, through the so-called hubs formation [18]. This is defined by Christaller as a hierarchical process, in which there is an automatic association between the urban center and the area of influence from the center. Lösch [22] took Christaller's empirical observations more systemically and regionally, but his model was based on industrial production (Christaller's system was based on the production of services).

However, Christaller's and Lösch's models did not address three very important issues: (a) an analysis on the consumer demand side was not present; (b) the function of costs in relation to location was not considered and, for this reason, they did not consider the cost of urban land and the spatial variability of the price and productivity of the productive factors; (c) the different productions were aggregated on the territory without an interdependence mechanism on the side of possible complementarity effects in the demand, and on that of possible input - output links in the offer. In a nutshell, in the founders' formulation, the model of central locations creates, from an analytical point of view, a hierarchy of cities without cities, where the city appears to be a concentration of residential activities, a large labor market and an efficient way of organizing of social production.

Around the 1950s, numerous applications around the world began, starting from an approach on territorial hierarchies of the input-output type [23–26] to the problem of planning transport, the use of gravitational models.

In the sixties, Izard published Methods of Regional Analysis which represents a fundamental text for probabilistic analysis at regional level. After him a large production of urban models developed. The most important contributions are Wingo [27], Alonso [28] and Lowry [29]. They dealt with the problem by following the line of probabilistic techniques thanks not only to statistics and mathematical theories, but also to the concept of entropy and related complex models.

Richardson, in 1975 [30], conducts spatial analyses following the kinetic theory of gases on the line of probabilistic techniques and on the concept of entropy and lays the theoretical foundations for representing reality through complex models.

The seventies also saw the evolution of management models to represent the territory. he first multi-objective and multi-criteria models are due to Van Delft and Nijkamp [31]. The analogy with the structure of a regional or urban economy also lies in the diversification of the products. The variety of a regional context can be "considered as a strategy to protect regional income from sudden sector-specific asymmetric shocks" [32, p. 53].

As suggested by Philip McCann and Frank van Oort [33], the main concept behind these premises is that urban and regional growth, manifested as innovations, propagates from a main hub of growth (or a main city) to nearby towns and cities of a lower order. Innovations, knowledge and know-how once generated in a particular central location should propagate across regions from one location to neighbors. However, this leads to two possible spillovers associated with growth pole theory: backward connections and forward connections. The first effects are associated with services into the cities that provide input to urban activities, attracting people in the main hub. The second ones are related to urban activities that use the results of new activities, or expand existing activities. However, this can lead to unexpected effects, such as when the growth pole attracts so much people and cumulative growth that it drains the surrounding areas. This therefore leads to a further polarization of urban growth, limiting growth elsewhere [34]. More recently, this theoretical framework has been applied in different studies of urban and regional growth [35, 36]; of agglomeration and innovation [37] and of employment growth and resilience [38].

These studies therefore argue that there is an urban product cycle concept in which urban activities are more easily developed in different metropolitan areas (the main hubs) with a diversified industrial structure and a diversified skills base, while in the end the mature urban activities or products are decentralized towards the hinterland or the peripheral areas (the secondary hubs).

However, the authors consider essential to insert an additional factor that reads and interprets the development of the urban systems (and their internal hierarchization) through the analysis of the (migratory, permanent, commuting, etc.) flows between the various towns or cities (or hubs) of the urban system itself. Each town (city) or hub is characterized by its own attraction potential which expresses the proximity of the population of that city to that ones of the other centers of the entire urban system.

These factors, together with the identification of the territorial hierarchies, can still constitute a key interpretative efficacy of the analysis of urban systems, obviously with operational and scientific tools suitable for the contemporary.

In fact, the territorial-hierarchical phenomenon, topic that has been widely studied, can interpret (and therefore predict) the spatial distribution and size of the main hubs that constitute the urban system, aimed at regional and territorial growth. However, the territorial-hierarchical model does not take into consideration the evolution (or involution) of the intermediate centers [39]. This phenomenon analyzes the trends of main urban aggregates where the structure of the territory itself is organized through diversified specializations according to variable hierarchies. There is no single focal hub, but different hubs that spread, thanks also to the multidirectional movement of goods and people.

The theoretical set of flow analysis and the necessary adjustment of the line linked to the identification of territorial-hierarchical model lead the authors to a new methodological and empirical hypothesis of the Central Place Theories, applied to the context under study in Sardinia. All this with the awareness that in recent decades, the digital revolution made great strides leading to the cancellation of space, distances, a space-time dissociation with consequences on lifestyle, work, etc., which can also be transferred to the city, upsetting traditional policies and consolidated hierarchies.

3 The CPTs with the Territorial-Hierarchical Model Applied in Sardinia (Italy): The First Step in Empirical Research

The review of the literature has revealed a significant consideration linked to CPTs integrated with the analysis of flows and territorial-hierarchical model for reading and controlling the gravitation phenomenon. In fact, it can be useful to strategic planning for proposing balanced scenarios between compatibility and diseconomies in the organization of the system and in the functions that the urbanized area can develop.

In particular, CTPs with the territorial-hierarchical model allows a reading of the territory through nuclei of different entities. From their aggregation, they form a reticular distribution capable, on the one hand, of analyzing the attraction potential of each individual nucleus and, on the other, of highlighting the aggregation potential of the different nuclei.

From the literature review and from the following analyzes, the authors conceive the aggregation potential as the capacity of several centers (strong, medium or small) to associate. This association is given not only by geographic, infrastructural (proximity, few impediments, mobility, etc.) and economic factors (primary and secondary services, work, etc.) but also by social ones (culture, language or dialects, etc.). The attraction potential, however, is established by the attractive force of a hub (almost always a strong urban cores) which, through tangible elements (roads, transport, rental of services, etc.) and intangible ones (governance, social policy, etc.) dynamics.) attracts a smaller center, which in turn, connected with the strong urban cores, can attract even smaller centers. This chain effect is what allows to revitalize the internal areas of an island.

Indeed, this is particularly important for island contexts because, both the attraction and aggregation potential, are bound by a specific limit that allows a specific study of the territory. The analysis of flows for obtaining an analysis of a reticular system will be applied in the context under study in the following paragraph.

With these premises, the authors want to understand if it is possible to give an urban response to the gaps that exist between the different hubs of the island contexts considering the attraction and aggregation of the nuclei of a particularly emblematic context, such as the island of Sardinia. In addition, Sardinia is not only an island system, but it is also particularly emblematic as a case study for three reasons.

The first is to be a Mediterranean island: Sardinia is at the center of the Mediterranean Basin [40] and, with an area of 23,813 km^2, it is also one of the largest islands in the area of the same basin. This allows to have common characteristics with other Mediterranean islands and therefore to be able to replicate the study.

The second reason is to be a particularly sensitive context. In the European programming 2014–2020 [41: 4–35], Sardinia belongs (together with Abruzzo and Molise) to the Italian regions with great difficulty in economic and social development.

The third motivation concerns the geography of places. The Sardinia region is inside the National Strategy for the Italian internal Areas (NSIA, in Italian: *Strategia Nazionale per le Aree Interne Italiana*—SNAI). In NSIA, the peculiarities of the territory are seen as a fundamental potential to contrast the phenomenon of depopulation and promote the economic and social development [42, 43]. In addition, SNAI describes the Italian territories not only with a strong gap between inland and coastal areas, but also with a polycentric articulation that allows the territory to be divided into historical subsystems (large, medium, small urban systems; and internal areas). To obtain the nuclei and their potential of attraction and aggregation, the authors first consider the historical regions of Sardinia and the Regional Landscape Plan (RLP) that allow a first schematic of the area (Fig. 1).

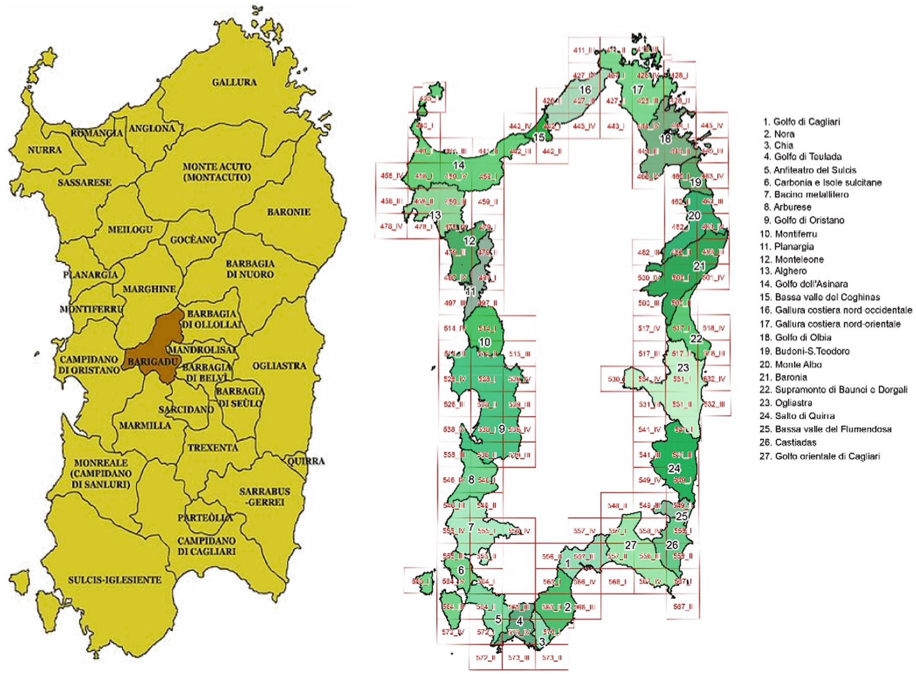

Fig. 1. Historical Regions of Sardinia (left). Source: [44] Regional Landscape Plan (right). Source: [45]

The Historical Regions of Sardinia are territorial groupings defined in 1952 which divided the island into administrative districts deriving from the Kingdom of Sardinia [46, 47] and the Regional Landscape Plan (RLP) is the legislative framework in Sardinia which guides and coordinates planning and sustainable development of the island in the coastal areas [48].

In other words, Historical Regions are a first aggregation of the territory which represent the functional dependencies between municipalities, so the strength with which municipalities attract [43]. As mentioned above, the RLP (Regional Landscape Plan) coordinates and plans sustainable development only on the coasts of the island. In fact, the RLP protects and enhances only the territories bordering the sea which by their nature are stronger in terms of economy, demography and services.

These two planning tools allow to think about the aggregation and attraction of the Municipalities of Sardinia. In fact, the Historical Regions summarize the aggregation potential between Municipalities, still valid today, and the RLP shows which are the centers of greatest attraction.

The main component analysis highlighted by Garau et al. [49] shows how the homogeneity of the groupings and the territorial-hierarchy in Sardinia are still directly deriving from the Sardinian historical regions, underlining the concept of their potential aggregation.

Instead, the RLP defines the coastal areas that are the most economically developed and those with the greatest number of services, namely, those areas that have a greater attraction force than the inland areas. Considering these factors, the authors analyze the relationships existing between different nuclei of Sardinia to have a general framework of development on a territorial scale.

Table 1 shows the different aggregations and centers of attraction through the CPTs with the territorial-hierarchical model, applied through the study of Historical Regions and the RLP. Subsequently, for each aggregation, the population is analyzed with Istat 2020 data [50]. These data are subsequently inserted in Fig. 2 and Fig. 3, where respectively a) the attraction centers and b) the attraction centers with the municipalities attracted appear.

Table 1. Aggregations, attraction hubs and population

Aggregations	Attraction centers	N° Municipalities attracted to each attraction center	Population divided into centers of attraction	Total population involved in the aggregations
Aggregation 1	Cagliari + Metropolitan area	49	539,095	600,305
	Isili	16	22,555	
	Senorbì-Muravera	18	38,655	
Aggregation 2	Iglesias-Carbonia	14	104,346	185,160
	Sanluri	24	80,814	
Aggregation 3	Lanusei-Tortolì	19	48,816	48,816
Aggregation 4	Olbia	23	138,293	175,936
	Siniscola	8	37,643	

(*continued*)

Table 1. (*continued*)

Aggregations	Attraction centers	N° Municipalities attracted to each attraction center	Population divided into centers of attraction	Total population involved in the aggregations
Aggregation 5	Sassari	16	238,601	282,223
	Ozieri	4	43,622	
Aggregation 6	Oristano	8	134,423	171,088
	Macomer-Bosa	20	36,665	
Aggregation 7	Nuoro	16	85,975	102,875
	Sorgono	12	16,900	

The analysis of the data (Table 1 and Figs. 2 and 3) shows seven aggregations given by the study of both the Historical Regions and the RLP. The seven aggregations (Table 1 first column), derive from the choice of 18 centers of attraction (Fig. 3, Table 1 second column) which historically perform mainly administrative functions defined by being provincial capitals or intermediate reference offices between the inner territory and the coastlines.

The municipalities attracted (Fig. 3, Table 1 third column) are the smaller centers which are geographically and economically connected to the centers of attraction.

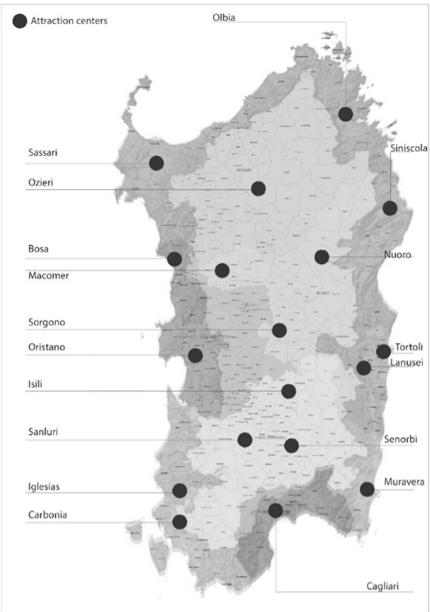

Fig. 2. Attraction centers - Leading municipalities

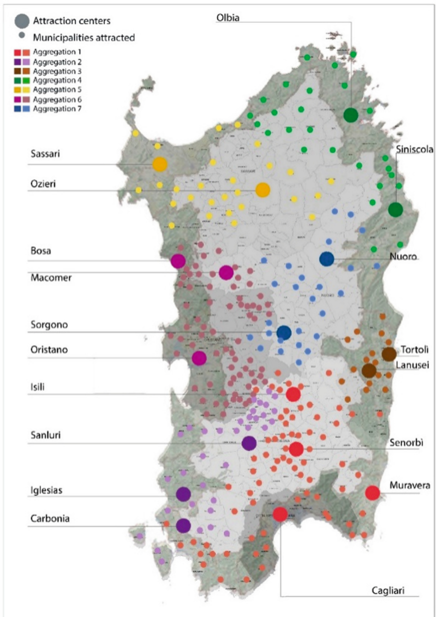

Fig. 3. Centers of attraction with the municipalities attracted

The number of municipalities attracted therefore depends on social dynamics that have strengthened over time through the construction of mobility networks, shared primary and secondary services, commuting and daily commuting. It is therefore clear that a center of attraction with a strong social impact for the whole island (for example Cagliari which attracts 49 surrounding municipalities) attracts more municipalities than a center which has a lesser impact than the regional system (for example Olbia which attracts 23 municipalities). Subsequently, the population was first divided into attraction centers (Table 1 column 4) and then total by aggregations (Table 1 column 5), to understand what the effective aggregating force is for each pole. This study was carried out for all 377 municipalities in Sardinia, however only 247 municipalities strongly attracted to attraction centers were taken into consideration. The 130 remaining municipalities, which will be treated in subsequent analyzes, are the border areas between aggregations, namely, those that are connected marginally with two or more aggregation centers.

4 Results on the Sardinian Reticular System Through the CPTs with the Flows Analysis and the Territorial-Hierarchical Model

The study conducted analysed the Territorial-hierarchical Model applied in Sardinia, highlighting, through the population variable, how the municipalities of the island have different social aggregations that distinguish today's urban structure. This paragraph wants to weigh these aggregations to insert them in different attraction levels through the CPTs analysis, the analysis of flows and Territorial-hierarchical Model. Indeed, confirming the authors' choice to take urban cores from the historically main centers, the analysis of the aggregations shows an organic system composed of the set of subsystems identified by the population that is able to achieve adequate territorial development conditions through strong nuclei of attraction. To achieve this goal, the CPTs with the territorial-hierarchical model is used with the analysis of flows. In fact, the different territorial hierarchies of the aggregations create a reticular system of the territory that allows the comparison between coastal centers and inland areas. On the basis of a bibliographic research on intra-regional aggregations [51–54], that the authors have not included in this article for space reasons, the territory was divided into different attraction/aggregation levels (Table 2).

Table 2 shows the hierarchy of the aggregations described above (Table 1). These aggregations do not all have the same weight in the regional system because the aggregation centers, that compose them, have a different level of attraction. For example, aggregation 4 composed of Olbia which attracts 23 municipalities (Strong Urban Core: intensity 2) and Siniscola which attracts 8 municipalities (Medium Urban Core: intensity 1) has a greater weight than aggregation 2 with Iglesias -Carbonia which attracts 14 municipalities (Medium Urban Core: intensity 1) and Sanluri which attracts 24 municipalities (Medium Urban Core: intensity 2). This is because the centers of attraction within the aggregation have lower attraction intensities. In addition, the 23 municipalities attracted to Olbia with a resident population of 138,293 inhabitants. are

Table 2. Aggregations, Attraction centers, Levels

Aggregations	Attraction centers	Levels
Aggregation 1	Cagliari + Area metropolitana	Strong Urban Core: intensity 1
	Isili	Medium Urban Core: intensity 1
	Senorbì-Muravera	Medium Urban Core: intensity 2
Aggregation 2	Iglesias-Carbonia	Medium Urban Core: intensity 1
	Sanluri	Medium Urban Core: intensity 2
Aggregation 3	Lanusei-Tortolì	Medium Urban Core: intensity 2
Aggregation 4	Olbia	Strong Urban Core: intensity 2
	Siniscola	Medium Urban Core: intensity 1
Aggregation 5	Sassari	Strong Urban Core: intensity 2
	Ozieri	Medium Urban Core: intensity 1
Aggregation 6	Oristano	Strong Urban Core: intensity 3
	Macomer-Bosa	Medium Urban Core: intensity 2
Aggregation 7	Nuoro	Strong Urban Core: intensity 3
	Sorgono	Medium Urban Core: intensity 1

much more significant than the 24 municipalities attracted to Sanluri which have a resident population of only 80,814 inhabitants.

Consequently, the levels shown in Table 2 are decisive not only by the number of municipalities attracted but also by the number of resident population.

In some aggregations, the leading municipalities are more than one so both the number of leading municipalities and the total population is greater than the average of the level to which they belong. For example, Senorbì-Muravera have a total of 18 towed municipalities and a total population of 38,655 inhab. Instead, Isili alone has 16 attracted municipalities and a population of 22,555 inhab.

Figure 4 shows these aggregations and the reticular system, allowing to have a reading of the territory from the coastal areas to the internal areas with the main key points of aggregation and attraction. In addition, Fig. 4 shows the analysis of the flows or the movement of the population from one municipality to another for work and study reasons.

Figure 4 shows 7 aggregations (red lines), each of which inside has municipalities with different levels of attraction (red and green circles). The black lines show the attraction that these municipalities exercise in the surrounding municipalities deduced from the analysis of flows, the population that attracts each individual center and urban hierarchization.

A strong centralization is visible on Cagliari, Olbia, Sassari and Oristano and subsequently on Nuoro which, although it has a minimum number of attracted municipalities, joins and involves a part of Sardinia that would otherwise be isolated and free of exchanges between municipalities.

This analysis shows that the Sardinian island system is strongly centered on the coastal areas and that the permeability between coastal and inner areas is still difficult. In this context, in fact, action should be taken on the potential of the resources located,

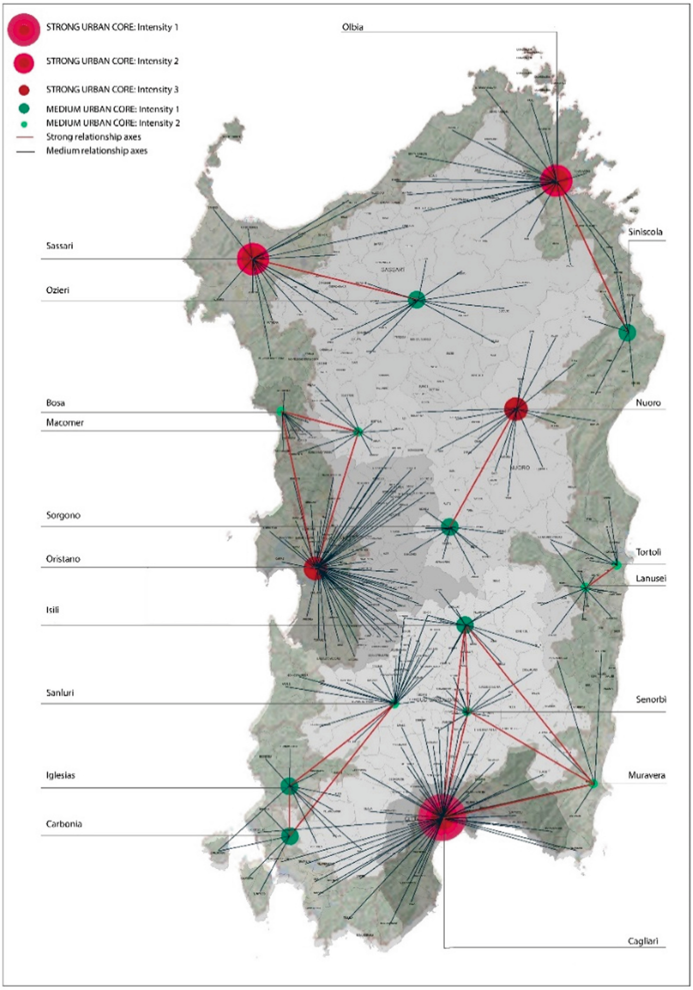

Fig. 4. Aggregations map (Color figure online)

on the daily trips that take place for study or work reasons and on the degree of employment that a municipality can offer.

5 Conclusions and Developments on Future Research

Starting from the theoretical assumptions of the CPTs, the research first outlines a territorial hierarchical model applied to Sardinia. Subsequently, through this model we study a reticular system that expands throughout the region. This is analyzed through the population variable that allows to study the analysis of flows to form a territorial-hierarchical model, repeatable in other contexts.

The proposed research therefore outlines a socio-territorial framework through the attraction and aggregation potential determined through two theories of central places based on flows analysis and the territorial-hierarchical model. This has led to the development of a reticular system that has made possible to understand both the dynamics existing between coastal areas and inland areas (Figs. 2 and 3). In addition, it was possible to delineate how these aggregated areas below certain levels can be a springboard for a most important economic and social system by concentrating the effects on an area of semicircular attraction, considering that the other half falls on the sea (Fig. 4). In addition, the assessment of the scenarios, which open up to the development of Sardinia in this article, is correlated with the consistency of the population of the entire island and the structural balance between the various geographical/economic areas. The results of the research, therefore, highlight a system formed by centers of attraction at different levels of attraction in the island system, and by common attractions that must be compared with the strongest centralities.

These analyzes would allow local politics to confirm or modify the settlement structures and the typology of services to be spread in the territory and to evaluate the size and typology of the propulsive places in the whole island to decide on the actions to be taken for the functional organization of the regional system. The main goal is to identify the main hubs in order to direct regional strategies in a targeted way towards smart urbanism [55, 56].

In other words, these aggregations (Fig. 4) can allow to evaluate important changes in the redistribution of primary activities and also the smaller municipalities can develop attractive affects to add to those that already characterize the centers of strong attraction described in this paper. Only with the analysis of the flows and with the construction of a hierarchical territorial model, which lead to the examination of direct effects on the regional reality, it was possible to measure the real size of the areas of gravitation and, therefore, to reason on the influence they exert towards other nearby cities and those further away with reference to growth and the effects, positive or negative, on development. Aggregations between strong urban hubs and medium urban hubs and their direct and indirect effects are important for the study and analysis of a closed system, such as islands. This is particularly important because in island contexts, which by their nature have a limited number of centers, the relationships between them must be strategically defined to allow for a homogeneous development between coastal and inland centers.

However, it is important to underline that, in order to have a complete framework on the urban dimension and on the articulation in the territory of the whole island, the data on the population must be crossed with those on mobility, geography, services and commuting, as determining and preparatory factors for intervening on the reorganization of the production system and on the interlocution between the internal and the coastal areas. This study allowed to make an initial reasoning for two types of future studies: 1) the possibility, through these aggregations, to study other sectors, for example to analyze tourism or cultural heritage for each aggregation would allow to have a much broader picture of the same aggregations; 2) the same analysis could be replicated not only on island contexts but also on non-island territories where the territorial hierarchy could go beyond the region.

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References

1. ONU World Urbanization Prospects. World Urbanization Prospects: The 2018 Revision (2018). https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf
2. Berry, B.J.I., Baskin, C.W., Christaller, W.: Central places in Southern Germany. Econ. Geogr. **43**, 275–276 (1967). https://doi.org/10.2307/143299
3. Getis, A., Getis, J.: Christaller’s central place. Theory J. Geog. (1966). https://doi.org/10.1080/00221346608982415
4. Van Meeteren. M., Poorthuis, A.: Christaller and “big data”: recalibrating central place theory via the geoweb. Urban Geogr. **39**, 122–148 (2018). https://doi.org/10.1080/02723638.2017.1298017
5. Brown, S.: Christaller knew my father: recycling central place theory. J. Macromarket. **15**, 60–72 (1995). https://doi.org/10.1177/027614679501500107
6. Eurostat. https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=Territorial_typologies_manual__island_regions#Classes_for_the_typology_and_their_conditions
7. Garau, C., Desogus, G.: A preliminary survey fora smart framework for the island contexts. In: 2nd IFAU International Forum on Architecture and Urbanism, pp. 596–703. Gangemi Editore, Italia (2018). ISBN 9788849236675
8. Access to European Union Law. Gazzetta ufficiale Comunità Europee (2000/C268/09) (2018). https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AC%3A2000%3A268%3ATOC
9. Territories with specific geographical features. https://ec.europa.eu/regional_policy/sources/docgener/work/2009_02_geographical.pdf
10. Analysis of the island regions and outermost regions of the European Union. https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/ilesrup/islands_part1_summary_en.pdf
11. Territorial typologies manual - island regions. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Territorial_typologies_manual__island_regions#Classes_for_the_typology_and_their_conditions
12. Novembre, C.: Le aree interne della sicilia tra problemi di sviluppo e ricomposizione territorial. Riv. Geogr. Ital. **122**, 235–253 (2015). ISSN 0035-6697
13. Andriotis, K.: Researching the development gap between the hinterland and the coast evidence from the island of Crete. Tour. Manag. **27**, 629–639 (2006). https://doi.org/10.1016/j.tourman.2005.02.005

14. Core, B.: Spatial dynamics of Mediterranean coastal regions. J. Coast. Conserv. **5**, 105–112 (1999). https://doi.org/10.1007/BF02802747
15. Internal Areas: Which Territories Are We Talking About? Explanatory Note on the Method of Classifying Areas. http://old2018.agenziacoesione.gov.it/opencms/export/sites/dps/it/documentazione/Aree_interne/Nota_metodologica_Aree_interne.pdf
16. Mulligan, G.F., Partridge, M.D., Carruthers, J.I.: Central place theory and its reemergence in regional science. Ann. Reg. Sci. **48**, 405–431 (2012). https://doi.org/10.1007/s00168-011-0496-7
17. Doran, D., Fox, A.: Operationalizing central place and central flow theory with mobile phone data. Annal. Data Sci. **3**, 1–24 (2015). https://doi.org/10.1007/s40745-015-0066-4
18. Scandurra, E.: Tecniche urbanistiche per la pianificazione del territorio. Editore Città Studi, Milano (1992)
19. Weber, A.: Theory of the Location of Industries, Chicago. Chicago University Press, Chicago (1909)
20. Christaller, W.: Central Places in Southern Germany. Prentice Hall, Englewood Cliffs (1933). Trans. C.W. Baskin, repr. 1966
21. Zipf deepened and applied the rank-size rule with appropriate weightings in 1949. Previously it was discovered by Auerbach in 1913 and subsequently modified and refined by Lotka in 1924. Zipf identifies a regularity of behavior in the distribution of the centers of a system, but “does not recognize an automatic association between the development of service activities and the demographic dimension of the center” (Scandurra, 1992; p. 69). In summary, in its simplest formulation, it provides statistical growth methods, where the urban centers of an area have a population inversely proportional to the position they occupy in a decreasing ranking by population: thus, the second city by number of inhabitants it should have a population equal to half that of the most populous city; the third city, a population equal to a third and so on. In these terms, the rule actually finds a very partial application, and therefore attempts have been made to make it more realistic by introducing forms of weighting of values
22. Lösch, A.: The Economics of Location. Yale University Press, New Haven (1954)
23. Harris, C.D.: The nature of cities and urban geography in the last half century. Urban Geogr. **18**, 15–35 (1997). https://doi.org/10.2747/0272-3638.18.1.15
24. Smailes, A.E.: The Geography of Towns. Aldine, Chicago (1966)
25. Brush, J.E.: The hierarchy of central places in southwestern wisconsin. Geogr. Rev. **43**, 380–402 (1953). https://doi.org/10.2307/211754
26. Isard, W.: Location and Space-economy. A General Theory Relating to Industrial Location, Market Areas, Land Use. Trade and Urban Structure. MIT Press, Cambridge (1956)
27. Wingo Jr, L..: Transportation and Urban Land, Resources for the Future. D.C., Washington (1961)
28. Alonso, W.: Location and Land Use. Harvard University Press, Cambridge (1964)
29. Lowry, I.S.: A Model of Metropolis. Rand Corporation, Santa Monica (1964)
30. Richardson, H.W.: Discontinuous densities, urban spatial structure and growth: a new approach. Land Econ. **51**, 305–315 (1975). https://doi.org/10.2307/3144948
31. Van Delft, A., Nijkamp, P.: A multi-objective decision model for regional development, environmental quality control and industrial land use. Pap. Reg. Sci. Assoc. **36**, 35–57 (1976). https://doi.org/10.1007/BF01944374
32. Torre, A., Wallet, F. (eds.): Regional Development and Proximity Relations. Edward Elgar Publishing, Cheltenham (2014)
33. McCann, P., Van Oort, F.: Theories of agglomeration and regional economic growth: a historical review. In: Handbook of Regional Growth and Development Theories. Edward Elgar Publishing (2019)

34. Richardson, H.W.: Regional and Urban Economics. Dryden Press, Hinsdale (1978)
35. Hewings, G.J.: Regional Industrial Analysis and Development. Routledge, Kondon (2017)
36. Galster, G.: Why shrinking cities are not mirror images of growing cities: a research agenda of six testable propositions. Urban Aff. Rev. **55**(1), 355–372 (2019)
37. Carlino, G., Kerr, W.R.: Agglomeration and innovation. In: Duranton, G., Henderson, J.V., Strange, W.C. (eds) Handbook of Regional and Urban Economics, pp. 349–404. Elsevier, Amsterdam (2015). https://doi.org/10.3386/w20367
38. Eriksson, R., Hane-Weijman, E.: How do regional economies respond to crises? The geography of job creation and destruction in Sweden (1990–2010). Eur. Urban Reg. Stud. **24**, 87–103 (2017). https://doi.org/10.1177/0969776415604016
39. Indovina, E.: La metropolizzazione del territorio Nuove gerarchie territoriali. Economia e società regionale, 3–4 (2003)
40. European Atlas of the Seas. https://ec.europa.eu/maritimeaffairs/atlas_en
41. European Structural and Investment Funds Regulations 2014–2020 (2015). https://ec.europa.eu/regional_policy/en/information/legislation/regulations/
42. State of Implementation of the Public Preliminary Investigation State-Regions/Autonomous Provinces. http://old2018.agenziacoesione.gov.it/it/arint/Stato_di_attuazione/stato_di_attuazione.html
43. Autonomous Region of Sardinia, Resolution n. 6/13 of 10.2.2015. http://www.regione.sardegna.it/documenti/1_274_20150211164206.pdf
44. La mia Sardegna. https://www.lamiasardegna.it/sardegna-regioni.htm
45. Regione Autonoma della Sardegna. Sardegna Territorio. http://www.sardegnaterritorio.it/j/v/1123?s=6&v=9&c=7426&na=1&n=10
46. Baldacci, O.: La casa rurale in Sardegna. Olschki, Firenze (2012)
47. Gulli, L.: Pasquale Mistretta. Storia e attualità di un percorso critic. Documenti di urbanistica. CUEC, Cagliari (2011)
48. Garau, C., Pavan, V.: Regional cultural heritage: new vision for preservation in Sardinia (Italy). J. Landscape Stud. **3**, 127–138 (2010)
49. Garau, C., Desogus, D., Coni, M.: Fostering and planning a smart governance strategy for evaluating the urban polarities of the Sardinian Island (Italy). Sustainability **11**, 4962 (2019). https://doi.org/10.3390/su11184962
50. Statistiche Istat. http://dati.istat.it/
51. AA.VV: Agriregionieuropa (2013). https://iris.unito.it/retrieve/handle/2318/141401/23224/agriregionieuropa_n34.pdf#page=102
52. Forte, P.: Aggregazioni Pubbliche locali. Franco Angeli, Milano (2011)
53. Lupo, S.: Tra centro e periferia. Sui modi dell'aggregazione politica nel Mezzogiorno contemporaneo. Meridiana **2**, 13–50 (1988)
54. Brunetta, G., Morandi, C.: Polarità commerciali e trasformazioni territoriali. Un approccio interregionale. Alinea, Firenze (2009)
55. Azzari, M., Garau, C., Nesi, P., Paolucci, M., Zamperlin, P.: Smart city governance strategies to better move towards a smart urbanism. In: Gervasi, O., et al. (eds.) ICCSA 2018. LNCS, vol. 10962, pp. 639–653. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-95168-3_43
56. Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., Yamu, C.: Urban digital twins for smart cities and citizens: the case study of Herrenberg, Germany. Sustainability **12**(6), 2307 (2020)