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The web of connections between tourism companies: Structure and dynamics

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ABSTRACT

Tourism destination networks are amongst the most complex dynamical systems, involving a myriad of human-made and natural resources. In this work we report a complex network-based systematic analysis of the Elba (Italy) tourism destination network, including the characterization of its structure in terms of several traditional measurements, the investigation of its modularity, as well as its comprehensive study in terms of the recently reported superedges approach. In particular, structural (the number of paths of distinct lengths between pairs of nodes, as well as the number of reachable companies) and dynamical features (transition probabilities and the inward/outward activations and accessibilities) are measured and analyzed, leading to a series of important findings related to the interactions between tourism companies. Among the several reported results, it is shown that the type and size of the companies influence strongly their respective activations and accessibilities, while their geographical position does not seem to matter. It is also shown that the Elba tourism network is largely fragmented and heterogeneous, so that it could benefit from increased integration.

'Make voyages! Attempt them! - there's nothing else...' (T. Williams)

1. Introduction

Tourism, probably the largest economic sector today, has fairly indefinite boundaries and comprises a wide diversity of organizations. A tourism destination, loosely defined as the goal of a traveler, is considered a fundamental unit of analysis for the understanding of the whole tourism sector [1]. From a socio-economic viewpoint it consists of a number of companies and organizations (public and private) who manage different and non-homogeneous attractions and services to be offered a visitor [2]. A tourism destination is a complex adaptive system sharing many (if not all) of the characteristics usually associated with it: nonlinear relationships among the components (companies and organizations), self-organization and emergence of organizational structures, and robustness to external shocks [3,4]. The dynamic set of relationships which form the connective tissue holding together the system's elements suggests a network approach to be indispensable for the understanding of a tourism destination. Several authors have used this perspective, mostly at a qualitative level [5–7]. Only a few, however, have adopted quantitative methods and tools in order to improve our knowledge of the structure and the dynamic behavior of a tourism system [8–12]. Today, more than ever, strong international competition induces an

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imperative to innovate to remain competitive. Many authors recognize that a prerequisite for innovation is the capability to cooperate and collaborate effectively. Tourism, more than most other economic sectors, involves the development of formal and informal collaborations, partnerships and networks, as well as the understanding of the patterns of linkages among the destination components and the assessment of the system's structure are crucial points [9,11,13,14]. Not less important is the effective access to local information and knowledge maintained by each participant of this intricate system.

With its origins going back to Flory [15] and Erdős-Rényi [16] works on random graphs, the area of complex networks [17–21] has established itself as one of the most dynamic and exciting alternatives for representing the structure and dynamics of the most diverse natural and human-made complex systems. One of the main reasons for the growing popularity and success of complex network investigations consists in its generality for representing and modeling virtually any system composed of discrete parts (e.g. Ref. [22]), encompassing from protein–protein interaction (e.g. Ref. [23]) to scientific collaboration (e.g. Ref. [24]). In addition, by representing any type of connectivity, complex networks are intrinsically suited for the investigation of more general types of dynamics. As a matter of fact, growing attention in complex network research has been focused on investigations of relationships between structure and dynamics (e.g. Ref. [18–20]). Three of the most important subjects currently pursued by complex network scientists correspond to: (i) the characterization of the structure of complex systems by using several topological measurements (e.g. Ref. [21]); (ii) the investigation of the modularity (i.e. community finding) of complex networks; and (iii) studies of the relationship between structure and dynamics of complex systems.

The current work reports a complex network approach to the comprehensive investigation of the complex system corresponding to the tourism destination in the Island of Elba. Each tourism agent is represented as a node, while the relationships between such agents are expressed by undirected edges. It is important to notice here that this is one of the first attempts at using network analysis methods in a tourism destination environment. The main objective of this exploratory work was to assess the usefulness of this approach for the understanding of the structural and dynamical characteristics of these systems. Therefore a 'minimalist' approach was taken leaving more detailed and refined analyses for future work. Nevertheless, our investigation encompasses all the three main approaches identified above, namely structural characterization in terms of several measurements, identification of communities, and investigation of the relationship between structure and function by using the *superedges* concept introduced recently [25]. The work starts by describing the construction of the tourism destination network and proceeds by briefly reporting the characterization of its structure and modularity. This is followed by the superedges approach to the structure:dynamics investigation.

2. The tourism destination network

The island of Elba (Italy), analyzed here, belongs to the Tuscany Archipelago National Park (located in the central Thyrrenian sea) and is the third Italian island. It is an important environmental resource and a significant contributor to the country's economy. Almost 500,000 tourists spend some 3 million nights per year in several hundred accommodation establishments. Elba is considered a mature tourism destination with a long history. Its has gone through a number of different expansion and reorganization cycles. The great majority of the stakeholders are small and medium sized companies, mostly family-run. Several associations and consortia operate on the island and try to recommend and develop different types of collaboration programs in an attempt to overcome the excessive 'independence' of the local companies [26,10].

Mapping a socio-economic system such as a tourism destination into a network is a difficult task as the choices in the definitions of nodes and connections may strongly affect the resulting graph and, consequently, its topological characteristics. In our case, we took into account the largest connected component of a destination network, in which, apart from some features described later on, all elements are considered to be equivalent and the connections are unweighted. Though simplistic, this approach has been able to provide interesting insights and to confirm the usefulness of the application of network analysis method in this field, paving the way for future more refined and thorough investigations. Moreover the adopted approach is consistent with many tourism studies where a first level of analysis of characteristics and behaviors of a tourism destination considers all stakeholders as being of the same 'type', without distinguishing their nature (public, private, single companies, associations etc.) as their first basic objective is (or should be) the balanced economic and social growth of the destination [1,2,5].

The destination network was built in the following way. The core tourism companies and associations operating at Elba were considered the nodes of a network whose links are the relationships among them. According to the local tourism board, the list of companies comprises 1028 items. The links reflect basic 'business' relations between organizations (i.e. commercial agreements, co-ownerships, partnerships, membership in associations or consortia etc.). They were collected by consulting publicly available sources such as associations listings, management board compositions, catalogs of travel agencies, marketing leaflets and brochures, official corporate records (to assess the belonging to industrial groups). These data were then verified with a series of in-depth interviews to 'knowledgeable informants': director of tourism board, directors of associations, tourism consultants etc. This triangulation [27] allowed to validate existing links and uncover others. The so-obtained network can be reasonably estimated to be nearly 90% complete.

Finally, based on the information available, all the nodes were recorded along with their membership to a specific type of business (8 types: e.g. hotels, travel agencies, associations etc.), geographical location (9 areas reflecting Elba's municipalities) and size (small, medium, large, estimated on the real size of the company). Overall, 8 different types, 9 geographical areas and 3 sizes are present. Table 1 shows the different node groupings according to the three main classifications.

Table 1
Types of Elba network operators.

Type of business		Geography		Size	
ID	Type	ID	Location	ID	Size
1	Associations	1	Porto Azzurro	1	Large
2	Cultural resources	2	Portoferraio	2	Medium
3	Food and beverage	3	Capoliveri	3	Small
4	Hospitality	4	Rio Marina		
5	Intermediaries	5	Rio nell'Elba		
6	Public organizations	6	Campo nell'Elba		
7	Transports/rentals	7	Marciana		
8	Other services	8	Marciana Marina		
		9	All island		

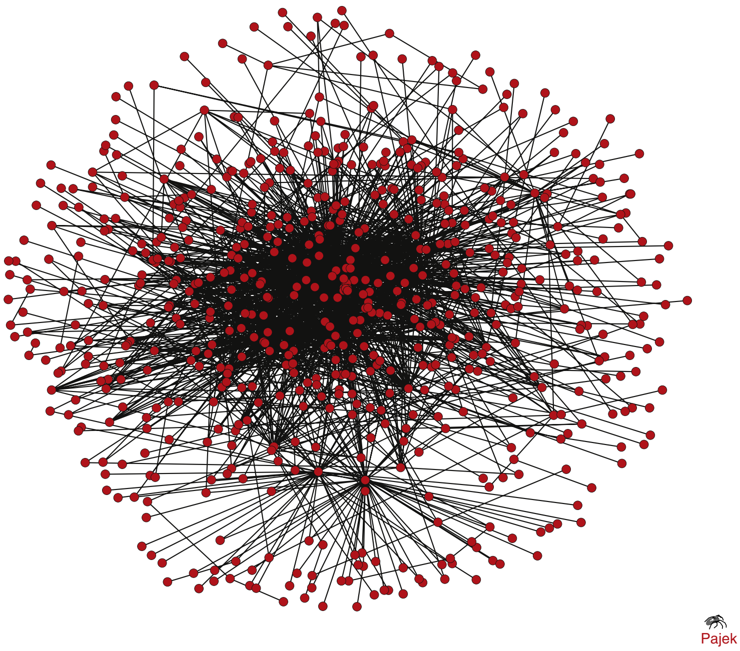


Fig. 1. Main connected component of the Elba tourism destination network.

In summary, besides the coarse classification described above, all tourism stakeholders are assumed to be of the same type, belonging to the same network and their connections are undirected, unweighted links that may be interpreted as basic information exchanges or acquaintance relations between them.

3. Characterization of the tourism destination network

The main connected component of the destination network is shown in Fig. 1.

Complex network analysis methods were used to investigate the topological characteristics of the system (for definitions and formulas see Ref. [21]). The obtained measurements, shown in Table 2, were calculated by using available software packages (Pajek, Ucinet) complemented by some Matlab programs developed by one of the authors. The degree distribution follows a power-law $P(k) \propto k^{-\gamma}$ where $\gamma = 2.32 \pm 0.27$. The scaling exponent and its standard error were calculated according to Clauset et al. [28]. For the analyses performed in the rest of this paper, only the main connected component of the Elba network (Elba_CC) was taken into account; the values are reported in Table 2.

A modularity analysis was also performed. The network nodes were divided into groups (modules) according to their typology as tourism operators and to the geographical location inside the island. The modularity index [29] of this partitioning was calculated (it is shown in Table 3). Moreover, the method proposed by Clauset et al. [30] was used to identify algorithmically a possible community structure of the network (reported as CNM in Table 3). As a comparison [31], the last row gives the values calculated (CNM) for a network of the same order, size and degree distribution as the Elba network with a random distribution of links (values are averages over 10 realizations).

It is important to note that the groups identified by using this method (CNM) are different in number and composition from the others (geography and type). The last column of the table contains the average modularity over the groups (modularity/number of groups), which is shown in order to better evaluate the different results (different methods resulted in different number of modules). It must be observed that the sizes of the majority of the modules identified by the CNM

Table 2
Values of several measurements calculated for the Elba tourism destination network and for its main connected component (Elba_CC).

Metric	Elba network	Elba_CC
Number of nodes	1028	627
Number of edges	1642	1642
Density	0.003	0.008
Disconnected nodes	37%	–
Diameter	8	8
Average path length	3.16	3.16
Clustering coefficient	0.050	0.08
Proximity ratio	34.10	12.77
Average degree	3.19	5.21
Average closeness	0.121	0.326
Average betweenness	0.001	0.003
Global efficiency	0.131	0.353
Local efficiency	0.062	0.102
Assortativity coefficient	−0.164	−0.175

Table 3
Modularity analysis of the Elba network.

Grouping	Number of groups	Modularity index	Average modularity
Geography	9	0.047	0.0052
Type	8	−0.255	−0.0319
CNM	11	0.396	0.0360
CNM (random)	12	0.367	0.0306

algorithm fall within the resolution limits set by Fortunato and Barthélemy [32], thus suggesting the existence of a finer structure. However, for the objectives of the present investigation, such an analysis was not conducted further.

The fact that the randomized network has a lower but similar modularity with respect to that obtained by using a community detection algorithm on the original network is an indication that a distinct modular structure exists even if it is not very well defined or highly significant [31]. It can be said that in this socio-economic system the topology generated by its degree distribution induces a certain level of self-organization which goes beyond pre-set differentiations (by geography or type) of the agents.

All in all, the main findings of the analysis of the main structural characteristics of the Elba network can be summarized as follows:

- The network shows a scale-free topology (power-law behavior of the degree distribution) which is consistent with that generally ascribed to many artificial and natural complex networks, moreover it shows a certain degree of small-worldness as shown by the proximity ratio;
- The general connectivity is very low (link density) with a very large proportion of disconnected elements;
- Clustering is quite limited, as is the efficiency, both at a local and global level;
- Assortativity is negative, contrary to general findings that show positive values for social networks;
- Modularity is generally very low. In one case, i.e. type of business, it is negative. This means that companies of the same type (e.g. hotels) tend to connect with some other company which runs a different business.

An extensive discussion of the implications of these results from a 'tourism' point of view is beyond the objectives of this paper (the interested reader can see Ref. [33]). Here, however, it is important to note the following issues.

The importance of network analysis methods applied to a tourism destination is twofold. First, they offer a way to quantify in an objective manner a number of characteristics that have been assessed so far only in qualitative manner. Degrees and other centrality quantities can help in acknowledging the most important stakeholders while the other metrics reported in Table 2 provide quantitative evidence in favor of recognizing that the network of Elban tourism operators is very fragmented in nature. In tourism terms this means that the local stakeholders exhibit a very low degree of collaboration or cooperation. This trait, known for the destination under study [26,10], can be quantified by considering the clustering and assortativity characteristics.

The study of modularity further confirms this finding. The system seems to exhibit self-organization properties which lead to the formation, to some extent, of an agglomeration of ties and produces a number of informal communities and an informal community structure. The information contained in the geographical or business typology data does not represent the communality characteristics, and the modularity solutions found in this way are non-optimal. From a destination management viewpoint, this result is important. It can provide indications on how to optimize some performance, for example optimal communication pathways or even productivity in collaborations, overcoming rigid traditional subdivisions, and offers a more practical tool to go along with the ideas and practices of an adaptive approach to the management of a tourism destination which has been advocated by some scholars [34]. Sadly, this is a quite common phenomenon in many tourism destinations. Similar tourism operators seem to dislike each other more than trying to combine their resources (at least some) in order to better cope with the market. A significant example of strong competition. These conditions

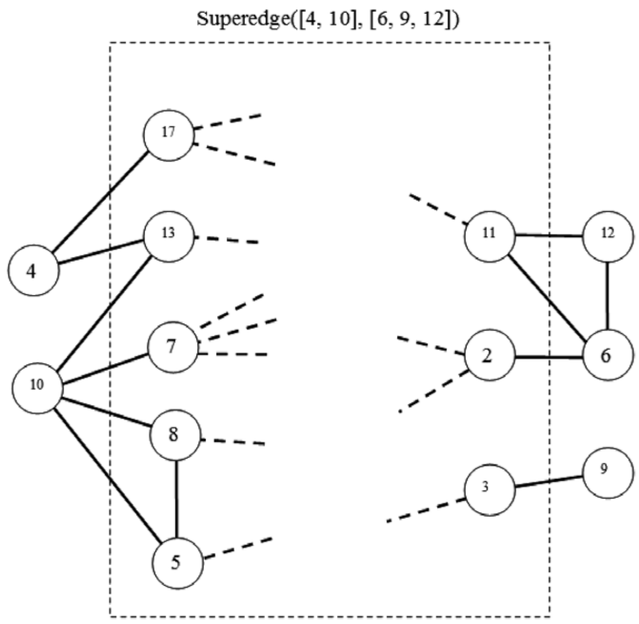


Fig. 2. Illustration of the superedge approach. Two sets of nodes are first selected as input (in this example [4, 10]) and output (6, 9, 12). Then the connectivity between these two sets is quantified in terms of the number of paths of different lengths between those sets. The dynamics induced over the output nodes implied by stimulation of the input set (e.g. liberation of moving agents at those nodes) is also quantified in terms of a set of respective measurements. Finally, the structural and dynamical features are investigated for the identification of possible relationships (e.g. correlations).

are also problematic for an efficient flow of information and knowledge through the social system, and this may affect its capabilities for innovation and future competitiveness. These considerations, again, are in general agreement with the previous studies performed by using more traditional qualitative techniques [26,10], and also provide additional insights about specific aspects of the interactions.

The second important outcome is that with a network representation it is possible to perform numerical simulations. Indeed simulation techniques are receiving increased attention as a powerful method to support complex analysis and planning activities for social and economic systems [35]. Information and knowledge flows in a destination, for example, are important factors for the general 'well-being' of the system, and the manner in which the diffusion unfolds influences the competitive advantage of both the destination and individual actors, and may affect their planning of future actions [36]. Suitable models and simulation techniques can be of great value to build and evaluate scenarios under different conditions and modifications to the network topological characteristics.

4. The superedges approach to structure and dynamics

The above characterization of the tourism network was restricted to *static* topological features. Because real tourism is a dynamical process, it becomes important to consider also the study of its possible *dynamics*. A comprehensive approach to investigating and relating structure and dynamics in complex systems, herein called the *superedges approach*, was reported recently [25]. This approach is founded on the treatment of a complex network as a dynamical system, considering subsets of nodes as respective input and output for a flow of dynamical interactions as illustrated in Fig. 2.

For each specific choice of input and output, the connectivity between these two sets of nodes is characterized comprehensively in terms of the number of paths with distinct lengths extending from the input to the output (other measurements, such as the properties of the nodes along the identified paths, can be also considered). Such an approach provides a substantially more comprehensive characterization of the topology of the connections than the typically used measurements of node degree and shortest paths (actually, the shortest paths are naturally incorporated into the superedges approach). Observe also that the obtained distribution of paths on itself yields a comprehensive characterization of the *structure* of the network with respect to the chosen input and output sets. Now, the functioning of this configuration can also be studied by adopting a specific type of dynamics (e.g. traditional random walks, self-avoiding random walks, Ising, or integrate-and-fire neuronal models). The choice of the specific type of dynamics should reflect the nature of the problem under investigation and the respective questions which are being posed. In this work, we consider self-avoiding random walk in order to model the dynamics of interactions between companies [37–39]. The effectiveness of random walks for modeling real-world complex phenomena has been corroborated by its application to effective WWW search engines [40]. Though simple, self-avoiding walks are more purposeful than the traditional random walk, in the sense of providing less redundant movements along the networks.

Having chosen the specific dynamical rules, the network is stimulated from the input set of nodes (e.g. by liberating moving agents), while the respective effect over the output set is monitored and characterized in terms of a set of measurements. Here we quantify the dynamics of interactions between pairs of nodes in the network in terms of the

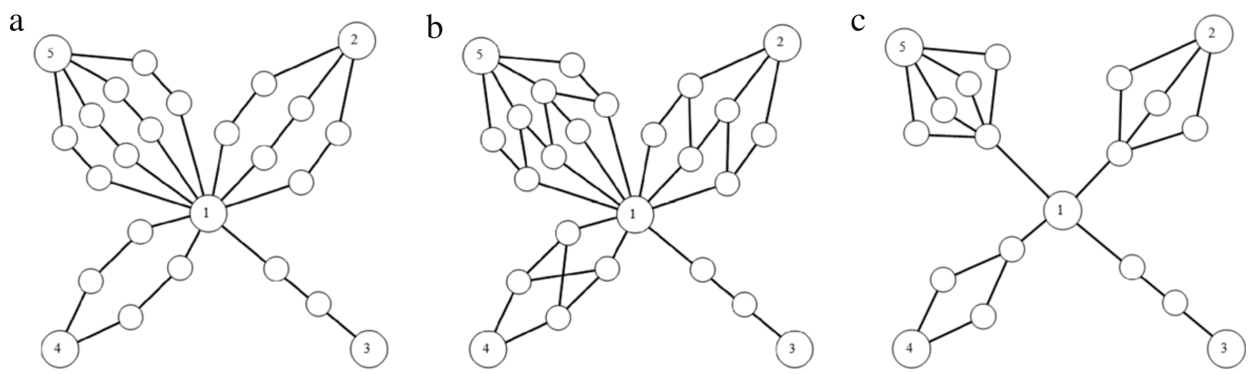


Fig. 3. Three reference situations regarding the relationship between the number of paths and transition probabilities between pairs of nodes. See text for explanation and discussion.

respective *transition probabilities*. More specifically, the transition probability from a node i to a node j after h steps, henceforth represented as $P_h(j, i)$ quantifies the chances that the moving agent will be at node j after h steps of the self-avoiding walk, having departed from node i. We use the algorithm described in Ref. [25] in order to calculate the exact transition probability values. At the end of such simulations, we have a set of structural measurements and a set of measurements of the dynamics, which can then be related for instance by using Pearson correlation coefficient [21,25].

Therefore, the superedges approach to relating structure and dynamics involves the following four basic steps: (i) selection of the input and output sets of nodes; (ii) characterization of the connectivity between these sets by considering the number of paths of distinct lengths interconnecting those sets (other complementary measurements can be used); (iii) stimulating some type of dynamics through the input set and measuring the dynamics implied onto the output set; and (iv) relating the obtained structural and dynamical features. Though the superedges approach is underlain by these main steps, the specific decision about what measurement and dynamics to adopt are intrinsically related to each specific problem.

The relationship between the number of paths of a given length h between a node i and a node j (a topological measurement) and the transition probability from node i to node j (a dynamical measurement) deserves particular attention, as it provides valuable insights about the relationship between structure and dynamics in the investigated system. Fig. 3(a) shows a network where node $i = 1$ is connected to four other nodes (2 to 5) through several paths of length 3, more specifically: $Q_3(1, 2) = 3$; $Q_3(1, 3) = 1$; $Q_3(1, 4) = 2$; and $Q_3(1, 5) = 4$. The respective transition probabilities are: $P_3(2, 1) = 3/10$; $P_3(3, 1) = 1/10$; $P_3(4, 1) = 2/10$; and $P_3(5, 1) = 4/10$. Therefore, in case of multiple independent paths as in Fig. 3(a), the transition probability will be directly proportional to the number of such paths. Such independent long range paths are also related to the presence of chain and tail motifs [41]. Consider now the network depicted in Fig. 3(b). Now we have $Q_3(1, 2) = 5$; $Q_3(1, 3) = 1$; $Q_3(1, 4) = 4$; and $Q_3(1, 5) = 7$, and $P_3(2, 1) = 7/40$; $P_3(3, 1) = 1/10$; $P_3(4, 1) = 2/10$; and $P_3(5, 1) \approx 0.22$. So, it is clear that interdependencies between the paths tend to break the correlation between the number of paths and the transition probabilities. Yet another possible situation is shown in Fig. 3(c), for which $Q_3(1, 2) = 3$; $Q_3(1, 3) = 1$; $Q_3(1, 4) = 2$; and $Q_3(1, 5) = 4$, and $P_3(2, 1) = P_3(3, 1) = P_3(4, 1) = P_3(5, 1) = 1/4$, i.e. though we have the same number of paths of length 2 between nodes 1 to 5 as in Fig. 3(a), the respective transition probabilities are completely different, being determined by the first connections established by node 1. Each of these three configurations, which correspond to important organizational aspects of the investigated network, can be identified by considering the respective scatterplot of transition probabilities in terms of the number of paths for each respective h. For instance, a strong correlation between the number of paths and transition probabilities suggests the predominance of independent paths such as in Fig. 3(a). The situation involving several cross-connections between the paths will lead to decreased correlation, characterized by smaller probability transitions for the same number of paths as would be obtained in the case of independent paths. The third situation implies complete loss of correlation between the dynamics and structure. For such reasons, the joint consideration of the structural (number of paths) and dynamical (transition probabilities) measurements presents good potential for characterizing and understanding the complex systems under analysis.

In the following section we report the configuration and application of the superedges approach to the analysis of the relationship between structure and function in tourism destination networks.

5. The superedges analysis of tourism networks

Basically, there are four main aspects to be specified while applying the superedges approach: (a) the choice of the input and output sets; (b) the choice of the measurements of the interconnection topology; (c) the choice of the dynamics; and (d) the choice of the measurements of the dynamics. The selection of each of these aspects respectively to tourism destination networks are explained in the following.

Input/output Selection: In order to obtain a systematic investigation of the relationship between the involved companies, we considering each possible node as input and output, implying a total of $N(N - 1)$ input–output configurations. Therefore, we will be taking into account all pairwise interactions between nodes.

Structural measurements: In this work, we focus attention on the number of paths of distinct lengths, from $h = 1$ to 3, between each pair of node, as well as the number of nodes reachable from each node after h steps. This approach provides a comprehensive characterization of the connectivity between the nodes, intrinsically including the shortest paths. The selection of such a comprehensive set of measurements is justified because they reflect the existing potential relationship between the companies. In this work we consider the number of paths of length h between two nodes i and j, hence $Q_h(i, j) = Q_h(j, i)$, as the main topological superedge measurement. We also consider the total number of nodes which are reachable from each specific node i after h steps, which is henceforth represented as $T_h(i)$.

Choice of dynamics: The interactions between companies often take place through pairwise communication and querying, which typically induces chains of contact. For instance, one company may inquiry about a service availability to another company, which in turn may contact another, and so on. Naturally, such chains of contacts avoid going through the same company more than once. In this work we model such contacting interactions in terms of self-avoiding walks initiating at the input set of nodes and progressing through the network until the walk can proceed no longer or a fixed number H of steps is exceeded. Such a dynamics properly reflects the chain of contacts between companies as well as the avoidance of repeated contacts. Its main limitation is that it does not take into account possible preferential interactions between specific companies. Though preferential self-avoiding walks can be implemented in principle, we currently lack information about the preferential links between companies.

Dynamical measurements: By simulating a large number of self-avoiding random walks initiating at the input node i, it is possible to estimate the transition probabilities $P_{(j,i)}$, parametrized by the path length h, between the input and output (j) nodes. Such probabilities supply important information about the interactions resulting from the chosen dynamics.

6. Superedges analysis of the Elba tourism network

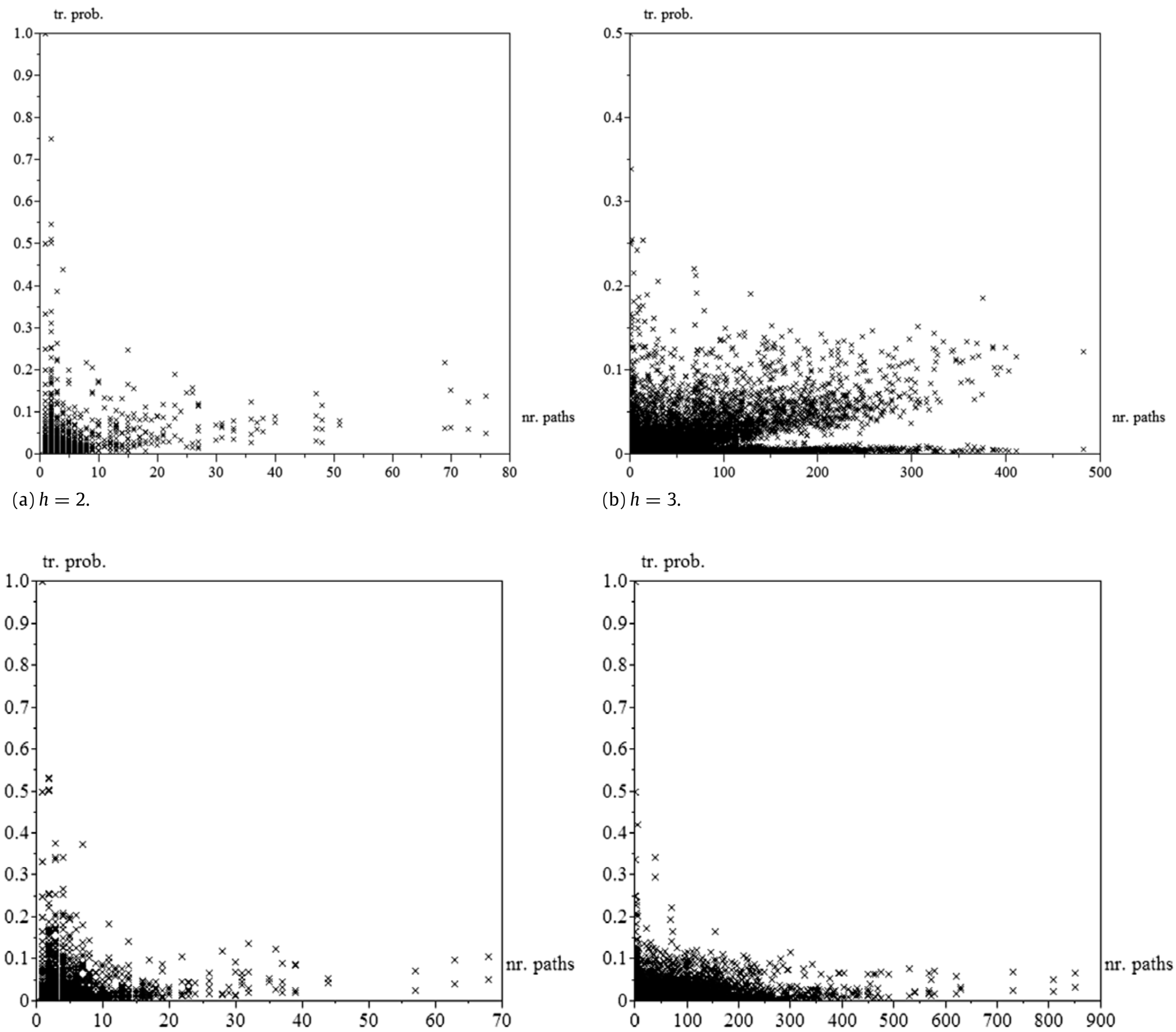
Having described and discussed the structural and dynamical superedges measurements, we now proceed to their application to the real-world tourism destination of the Island of Elba. We restrict our attention to $h = 1, 2$, and 3. The isolated nodes of the original network were not considered in the superedges investigation, leaving out 627 nodes to be considered in our analysis.

We start by considering possible correlations between the number of distinct paths and the respective transition probabilities between pairs of nodes for each $h = 2$, and 3 (all transitions are equal to 1 for $h = 1$). Fig. 4(a, b) show the scatterplots obtained for these two situations, each involving a total of 414 736 edges. The lack of positive correlation between these pairs of structural:dynamical measurements obtained for $h = 2$ (Fig. 4a) makes it clear that the paths of length 2 between pairs of nodes in the Elba tourism destination network are intensely interdependent, implying situations involving several paths to have small transition probabilities because of deviations along highly interconnected paths. A different relationship was obtained for $h = 3$ (Fig. 4b), which includes two main components: a cloud of correlated points and a group of points with high number of paths of length 3 and respective low transition probabilities. While the cases belonging to the former relationship are likely to correspond to relatively independent paths of length 3, the cases in the second group are related to intensely interdependent paths. Overall, the number of paths and transition probabilities between pairs of companies varied intensely, confirming great heterogeneity of the interconnections between the involved companies. The results in Fig. 4(b) indicate that several of the Elba tourism companies can intercommunicate through independent paths, suggesting little integration between the intermediate companies (i.e. those falling along the paths between each pair of company). An immediate consequence of this property is that the intermediate companies will, in average, exhibit limited potential for providing additional information about other companies (the paths of length 3 between pairs of nodes in the Elba network are largely independent one another). Fig. 4 also shows the respective scatterplots obtained for rewired versions of the Elba network (preserving the degree distribution). It is clear that the correlation, related to the independent paths, is completely lost in the more uniformly connected structure obtained through the rewiring.

Fig. 5 shows the distributions of the number of reachable companies at $h = 2$, and 3 with respect to the type, geography and size of the respective companies identified by the colors and symbols. It is clear from the scatterplots identifying the types of the companies that the number of reachable nodes at $h = 2$ and 3 depends of the type of companies. For instance, the companies of type 4 (hotels) tend to reach few companies for $h = 1$ but can reach a large number of companies after 2 steps. On the other hand, companies of types 1 and 5 (respectively associations and intermediaries) tend to reach many companies at $h = 1$. The companies of type 1, 4 and 5 are capable of reaching several other companies at $h = 3$, while organizations of type 2 (entertainment and cultural resources) can reach varying numbers of companies for this same number of steps. At the same time, no clear trends can be inferred while considering the geography of the networks. The reachability is strongly dependent of the size of the companies, with companies of size 1 (large) tending to reach many other companies for $h = 1$ and 3. Similar tendencies are verified for sizes 2 (medium) and 3 (small).

All in all, in addition to the verified specific trends, the above results make it clear that the structural and dynamical properties of the considered companies depend strongly on their type and size, being much less affected by their respective geographical position.

By giving a 'physical' dynamical interpretation to these results, it is possible to summarize the outcomes as follows. The geographical subdivision does not seem to have any sort of influence on the reachability of Elban tourism companies. This is in agreement with the observed very low tendency to form 'geographic' communities coming from the static modularity analysis. Some companies or organizations (mainly associations and intermediaries) seem to be very active in reaching or



(a) $h = 2$.

(b) $h = 3$.

(c) $h = 2$.

(d) $h = 3$.

Fig. 4. The scatterplots of the number of distinct paths and transition probabilities for the Elba tourism destination network with respect to $h = 2$(a) and 3(b). Two types of edges can be noticed in the latter configuration, corresponding to correlated and uncorrelated groups. The results obtained for the rewired version of the Elba network (c–d) do not show any definite correlation between structure (number of paths) and dynamics (transition probabilities).

being reached by other companies. The size of the company or organization matters, as larger entities tend to be more active than the smaller ones. This picture is in full agreement of what is known of the behaviors of tourism operators in the destination (see for example Ref. [10] or Ref. [26]). However, the identification of the specific trends exhibited by each type of company only became clearer through the superedges integration of the structural and dynamical features. By applying such an approach, and considering the correlations between the transition probabilities and number of paths, it was possible to identify two main groups of edges in the Elba network in the case of $h = 3$ (i.e. paths of length 3): one exhibiting virtually no correlation and another, larger group, being characterized by relatively strong correlation. This result implies that there are two type of longer range connections in the Elba network. The group with higher correlation is related to the presence of several independent paths between pairs of companies, revealing that several companies are connected along chains, therefore providing little possibilities of interactions between those companies. At the same time, the presence of a relatively high number of such independent paths also reveals a high level of redundancy of pairwise interactions, through different path lengths, between pairs of companies. In other words, one company will be able, on the average, to access another company through many alternative routes, but the companies along these routes will provide little in terms of integration with other companies and are, therefore, unlike to contribute to the integration and dissemination of information. The presence of many independent paths identified by the correlated group of edges for $h = 3$ also suggests that the Elba network is in an intermediate stage of growth, characterized by the presence of several chain motifs which are likely to be further interconnected along time, yielding a more integrated structure with more interdependent paths.

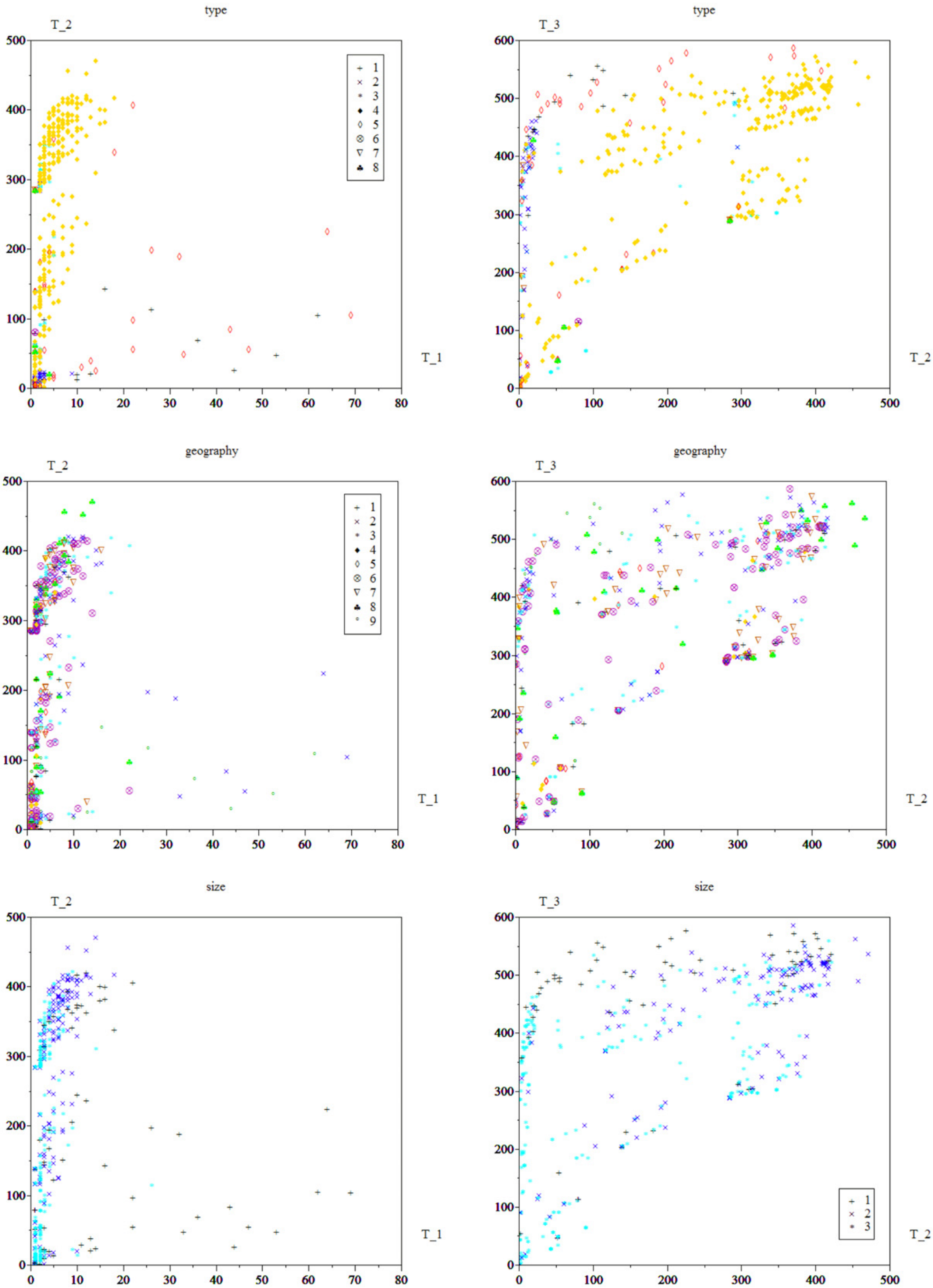


Fig. 5. The scatterplots of the number of distinct paths for the three classifications of the companies, namely *type*, *geography* and *size*.

7. Concluding remarks

Tourism destination networks are amongst the most complex real-world systems, involving intricate structure and nonlinear dynamics. Because of the great economical importance of such systems, it becomes increasingly important to devise effective means for describing, characterizing and modeling these systems so that their structure and dynamics are better understood, allowing predictions, identification of possible improvements, and simulations aimed at evaluating the effects of varying scenarios and conditions. At the same time, complex networks research is now a mature area catering for all such requirements, from the characterization of the structure of the interaction between tourism companies to the relationship with the respective dynamics of interactions and information exchange. The current article has brought these two important areas together with respect to the analysis of the Elba tourism destination network, a real-world structure which has been recently obtained through systematic and careful investigation including field data collection.

Although adopting a simplistic network representation of a tourism destination, this work has provided interesting insights into the structural and dynamical characteristics of the system which fully satisfies the basic objectives of this exploratory work. Future work, already under way, will provide a more detailed and sophisticated mapping for this system and improve the methods used here so as to better describe and understand a tourism destination system.

The main contributions of our work are listed and discussed as follows:

Complete real-world example of the superedges approach: This work represents the very first comprehensive application of the superedges approach to a real-world network. As such, special care has been invested in order to make the respective concepts and interpretations clear from the context of the specific application, namely tourism destination structures. In particular, each of the choices which have to be made regarding the superedges methodology – including input/output, structural measurements, dynamics and dynamical measurements – has been motivated and justified with respect to the tourism application. The methodology was first illustrated with respect to a hypothetical simple network of companies, and then applied systematically to the real-world Elba tourism destination structure. As such, this first complete example can be used as a application reference guide for researchers intending to apply the superedges approach to other specific problems.

Comprehensive structural characterization: This work has presented one of the very first comprehensive analysis of the topological characteristics of a 'real' tourism destination network, including traditional measurements, modularity as well as the number of distinct paths between pairs of nodes. A comparison, and the substantial similarity, of the outcomes with the previous knowledge of the relationships among the tourism companies located at Elba stakeholders [26,10] substantiates the effectiveness of our approach and results.

Comprehensive dynamical characterization: In addition to characterizing several structural properties of the tourism destination network, we performed a systematic investigation of a possible model of the dynamics of interactions between the involved companies, which was done by considering self-avoiding random walks. The effects of such a dynamics over the interaction between the companies has been effectively expressed in terms of the transition probabilities between pairs of companies. Two groups of edges have been clearly identified for $h = 3$, indicating the presence of a large number of independent connections between pairs of companies, implying that the companies along such independent paths are unlikely to contribute to further integration and sharing of resources and information, therefore being limited to acting mostly as intermediate outposts or relays. At the same time, the presence of such independent paths also suggest that the Elba network is still in development and that the intermediate relay companies will become eventually interconnected along time.

Practical implications: As for the static structural characterization, the results of the analysis conducted by using the dynamic superedges approach finds a justification and a verification in the established (qualitative) knowledge of the destination examined, its stakeholders and their behavior. This further confirms and reinforces the validity of the currently adopted approach. Although intriguing per se, the outcomes may have, at a destination management level even a bigger importance. A quantitative investigation method, with a strong theoretical basis, is able to provide descriptions and indications which, traditionally would have required long, and sometimes disputable, qualitative studies. The reliability of the conclusions one may find in combining the two approaches (qualitative and quantitative) can stand any comparison. The combination can be used in several ways, but principally in confirming or correcting a previous knowledge or the one coming from more traditional social studies. In our case, for example, we have seen it would be possible to improve the overall collaborative environment by considering our destination as a single 'geographical entity', disregarding any pre-set administrative division that, on the contrary, is the one normally used as a basis for the design of planning and policy actions. We have also identified, in an indisputable way, the stakeholders of this destination which would require the highest effort. It is possible, in other words, to reliably assign priorities to plans and actions and to distribute more productively resources (typically scarce) for their implementation. As many scholars in the field of tourism know, this is a crucial issue for an efficient and effective management of a destination and for favoring its socio-economic growth [36,2].

The future works implied by our currently described research include but are not limited to the following possibilities:

Analysis of other destination networks: It would be particularly interesting to apply the reported methodology to other destination networks, in order to allow comparisons between the respective structures and dynamics. Among the several related possibilities, it would be interesting to compare the Elba network with networks obtained for tourism regions in other continents, such as America and Asia, in order to search for similar and distinct properties. The reported methodology can also be applied as a means to obtain a comparative analysis between tourism destinations in the first and third world.

Analysis of multiple structures: A more refined data collection will allow to better specify the type and the nature of the connections between different companies and to provide weighted network analyses for the system, unveiling different behaviors with respect to what is presented here. Moreover, it will be possible to investigate how different subnetworks combine to form the overall destination network and what kind of hierarchical structures arise from this composition. Finally, the superedges analysis can be extended to investigate the interactions between different types of stakeholders in order to better evaluate the respective dynamical behavior.

Simulations: Given a network such as that analyzed in this work and its respective comprehensive characterization, it would be interesting to perform simulations involving the addition or removal of connections, in order to investigate effects of communication failures as well as the creation of new partnerships, and to assess the unfolding of processes such as information and knowledge transfer when the topological characteristics of the network are modified.

Inference of growth models: The comprehensive characterization of the Elba tourism destination network in terms of structural and dynamical features reported in this article has paved the way to attempts to obtain growth models capable of reproducing the observed structure, possibly under the effect of the respective dynamics. For instance, after starting with a small random structure, new connections could be established while taking into account regional proximity, possibly involving the path-regular knitted network [42] to interconnect the companies according to their positions. Such growth models would allow a yet more complete understanding of tourism destination systems.

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References

[1] J. Jafari, Encyclopaedia of Tourism, Routledge, 2000.
[2] N. Vanhove, Economics of Tourism Destination, Elsevier Butterworth-Heinemann, 2005.
[3] R. Baggio, Tour. Anal. 13 (2008) 1–20.
[4] B. Faulkner, R. Russell, Pacific Tour. Rev. 1 (1997) 93–102.
[5] L. Lazzeretti, C.S. Petrillo, Tourism Local Systems and Networks, Elsevier, 2003.
[6] A. Morrison, P. Lynch, N. Johns, Int. J. Contemp. Hosp. Manag. 16 (2004) 197–202.
[7] K. Pavlovich, Tour. Manag. 24 (2003) 203–216.
[8] N. Scott, C. Cooper, R. Baggio, Ann. Tour. Res. 35 (2008) 169–188.
[9] N. Scott, R. Baggio, C. Cooper, Network analysis and tourism: From theory to practice, Channel View, 2008.
[10] V. Tallinucci, M. Testa, Marketing per le isole, Franco Angeli, Milano, 2006.
[11] B. Bramwell, B. Lane, Tourism collaboration and partnerships: Politics practice and sustainability, Channel View, 2000.
[12] R. Baggio, Physica A 379 (2007) 727–734.
[13] C. Cooper, Ann. Tour. Res. 33 (2006) 47–64.
[14] N. Scott, C. Cooper, R. Baggio, Advances in Tourism Marketing Conference, Valencia, Spain, 2007.
[15] P.J. Flory, Molecular size distribution in three-dimensional polymers. I. Gelation, J. Am. Chem. Soc. 63 (1941) 3083–3090.
[16] P. Erdős, A. Rényi, On random graphs, Publ. Math. Debrecen 6 (1959) 290–297.
[17] R. Albert, A.L. Barabási, Statistical mechanics of complex network, Rev. Modern Phys. 74 (2002) 47–97.
[18] S.N. Dorogovtsev, J.F.F. Mendes, Evolution of networks, Adv. Phys. 51 (2002) 1079.
[19] M.E.J. Newman, The structure and function of complex networks, SIAM Rev. 45 (2003) 167.
[20] S. Boccaletti, V. Latora, Y. Moreno, M. Chavez, D. Hwang, Complex networks: Structure and dynamics, Phys. Rep. 424 (2006) 175.
[21] L. da F. Costa, F.A. Rodrigues, G. Travieso, P.R.V. Boas, Characterization of complex networks: A survey of measurements, Adv. Phys. 56 (2007) 167–242.
[22] L. da F. Costa, O.N. Oliveira Jr., G. Travieso, F.A. Rodrigues, P.R.V. Boas, L. Antiqueira, M.P. Viana, L.E.C. da Rocha, Analyzing and modeling real-world phenomena with complex networks: A survey of applications. arXiv:0711.3199.
[23] H. Jeong, S.P. Mason, A.L. Barabási, Z.N. Oltvai, Lethality and centrality in protein networks, Nature 411 (2001) 41–42.
[24] S. Lehmann, B. Lautrup, A.D. Jackson, Citation networks in high energy physics, Phys. Rev. E 68 (2003) 026113.
[25] L. da F. Costa, Superedges: Connecting structure and dynamics in complex networks. arXiv:0801.4068.
[26] H. Pechlaner, V. Tallinucci, D. Abfalter, H. Rienzner, Networking for small island destinations — The case of elba, in: A.J. Frew, M. Hitz, P. O'Connor (Eds.), Information and Communication Technologies in Tourism, Springer, Wien, 2003, pp. 105–114.
[27] W. Olsen, Triangulation in social research, qualitative and quantitative methods can really be mixed, in: M. Holborn (Ed.), Developments in Sociology: An Annual Review, Causeway Press, Ormskirk, UK, 2004.
[28] A. Clauset, C.R. Shalizi, M.E.J. Newman, arXiv:physics/0706.1062.
[29] M.E.J. Newman, M. Girvan, Phys. Rev. E 69 (2004) 26113.
[30] A. Clauset, M.E.J. Newman, C. Moore, Phys. Rev. E 70 (2004) 066111.
[31] R. Guimera, M. Sales-Pardo, L.A.N. Amaral, Modularity from fluctuations in random graphs and complex networks, Phys. Rev. E 70 (2004) 025101(R).
[32] S. Fortunato, M. Barthélemy, Resolution limit in community detection, Proc. Natl. Acad. Sci. USA 104 (2007) 36–41.
[33] R. Baggio, N. Scott, C. Cooper, Dondena Working Paper No. 7, 2008. http://www.dondena.unibocconi.it/wp7.
[34] B. Farrell, L. Twining-Ward, Ann. Tour. Res. 31 (2004) 274–295.
[35] C. Castellano, S. Fortunato, V. Loreto, Statistical physics of social dynamics, Rev. Modern Phys. 81 (2009) 591–646.
[36] J.R.B. Ritchie, G.I. Crouch, The Competitive Destination: A Sustainable Tourism Perspective, CABI Publishing, 2003.
[37] C.P. Herrero, Self-avoiding walks on scale-free networks, Phys. Rev. E 71 (2005) 016103.
[38] M.E.J. Newman, A measure of betweenness centrality based on random walks, Soc. Netw. 27 (2005) 39–54.
[39] S.Y. Yang, Exploring complex networks by walking on them, Phys. Rev. E 71 (2005) 016107.
[40] L. Dall'Asta, I. Alvarez-Hamelin, A. Barrat, A. Vázquez, A. Vespignani, Statistical theory of internet exploration, Phys. Rev. E 71 (2005) 036135.
[41] P.R.V. Boas, F.A. Rogrigues, G. Travieso, L. da F. Costa, Chain motifs: The tails and handles of complex networks. arXiv:0706.2365.
[42] L. da F. Costa, Knitted complex networks. arXiv:0711.2736.

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