Network analysis methods

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Tourism is a complex phenomenon whose main constituents are complex adaptive systems. The understanding of their characteristics and dynamic behaviors is of great importance for the good governance and operation of all components. One of the most effective methods for these studies focuses on the role played by the relationships among the actors and communities involved. For this purpose, network analysis methods are especially suitable (Baggio, 2017).

Network analysis (NA) is an umbrella term that refers to the wide set of techniques made available in the last years that allow mapping and analyzing the patterns of relations among the elements of a system. NA is grounded in the idea that a strong association exists between a system's structure and its functions or the dynamic processes that may be involved.

The main techniques stem from the quantitative methods of the mathematical graph theory and have provided a wide array of measures that, when well interpreted in the light of a good qualitative knowledge of the issues at stake, are able to provide outcomes and insights of interest from both a theoretical and 'practical' point of view (da Fontoura Costa et al., 2011).

Formally a network is a graph $G=(V,E)$, where V is a set of nodes (vertices, actors, elements) and E is a set of pairs of nodes called edges (links, arcs). Edges can be directed or undirected, or have an associated weight, a value that may represent a cost, a speed or an importance. This graph can be rendered numerically by a NxN matrix A (N is the number of nodes in the network), called adjacency matrix, whose elements are $A(i,j)=w$ if a link between node i and node j exists, or 0 otherwise (w is the weight associated to the link, if no weights are defined $w=1$). This abstraction allows using the methods of linear algebra for expressing the metrics that account for the properties of the network (see Figure 1). The general theoretical framework and the detailed explanation of the main metrics and their importance can be found in the vast literature on the subject (see e.g. Barabási, 2016).

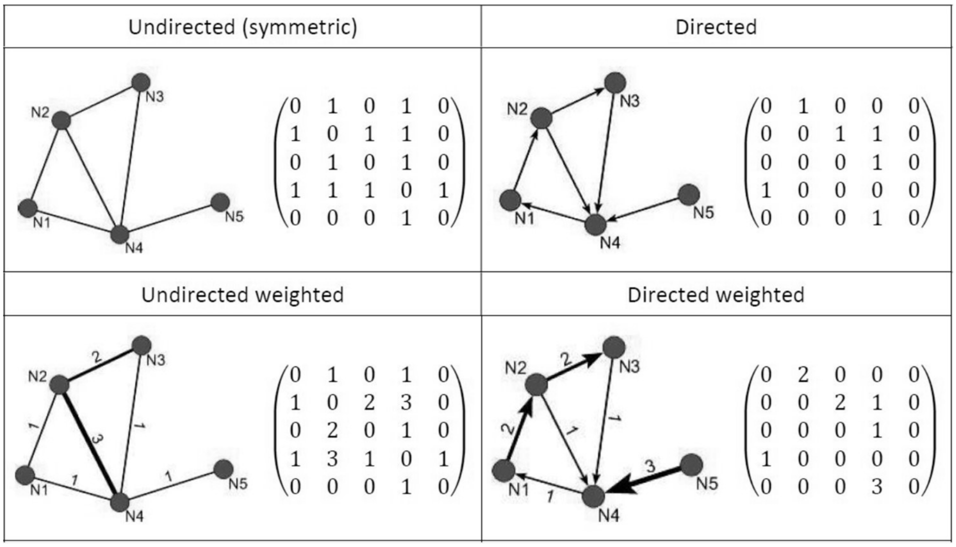

Figure 1 Four network types with their adjacency matrices

A network study starts with the collection of the data needed (nodes and links). For a tourism system the nodes usually represent the stakeholders of the system (typically a destination). The links are collected using various methods: survey, listings from associations, consortia, groups, official records on co-ownership etc. Frequency of connections or perceived importance can be used as weights. Once built the network, the study makes use of suitable software packages or libraries for some programming language for deriving measures that can be used for three levels of analysis:

- individual (microscopic) level: examines specific nodal properties such as: degree (number of links each node has), betweenness (number of paths passing through a node), closeness (average distance from a node to the others), clustering coefficient (local density of links around a node) that control the relative importance of a node within the network. Normalized version of these metrics is usually called centrality (e.g. degree centrality, betweenness centrality etc.);
- intermediate (mesoscopic) level: surveys the possible modular structure of a network, i.e. the quality of a division into modules (communities, clusters) whose nodes are more densely connected between them than to rest of the network. Several algorithms allow detecting these clusters (Fortunato, 2010). Hierarchical structures can also be uncovered in this way;
- global (macroscopic) level: describes the overall structure operationalized by quantities such as density (ratio of number of links present and maximum possible), average path length (mean distance between any two nodes), diameter (maximal shortest path), efficiency (capability of the system to exchange information). The most important and common measurement for describing the topology (structure) of a network is the probability distribution of the degrees $P(k)$ (termed degree distribution). Its mathematical form hints well at the general features of the network, its complexity, and its behavior when subject to a dynamic process. Typical degree distribution for many real networks has a power-law shape (i.e. $P(k) \sim k^{-\alpha}$). That is: few nodes have many connections (i.e. the hubs), while many others have only a few links. Other measures used to describe the macroscopic characteristics are the correlations existing between the distributions of different metrics, and the average values of the microscopic metrics over the whole network.

For its complex dynamic characteristics, and being essentially based on relationships of various kinds, tourism is a suitable target for a network analysis. Quality and quantity of the connections among companies, organizations and people are, in fact, crucial elements that determine the static and dynamic structural characteristics of the system. This (obvious) realization, is even more valid if we consider a destination, the basic entity, cornerstone for the whole phenomenon. NA studies, after a relatively slow start have seen an increased interest in the academic community and many interesting outcomes on the properties of these systems are now available (Baggio, 2017; Heidari et al., 2018; van der Zee & Vanneste, 2015).

In a typical tourism destination, a network analysis can provide interesting insights especially when combined with other information. At an individual level, the position of an actor (hotel, travel agency etc.) can be compared with other business outcomes to assess the relevance and the effects of the actor's connectivity patterns. The mesoscopic configuration can show what communities emerge and what their composition is, thus giving a more realistic picture than the one usually based on other segmentations (e.g. business types or geographical proximity). It is thus possible to assess, via simulations, the extent and the efficacy of a destination's cooperative character and convey policy suggestions to improve it and to favor creative and innovative practices. The global structural features allow evaluating the general dynamics of a destination. When complemented by a simulation of dynamic processes (e.g. knowledge transfer or opinion formation) can provide hints on ways to optimize them and on the management styles to adopt. More in general, all the characteristics of a destination network may be optimized with a suitable numerical simulation thus supplying possible scenarios useful for better informed policy setting or operational decisions (Baggio, 2017).

As an example, a destination network is examined in Figure 2. Panel A shows the network whose nodes (the stakeholders: hotels, travel agencies, service companies, public bodies etc.) are sized according to their degree (popularity) and colored based on their clustering coefficient, that can be interpreted as their cooperation attitude. Panel B has the degree distribution. The dotted line makes clear the power-law shape (some hubs and many nodes with few connections) that can be used for inferring the formation mechanism of the system. In this case it is compatible with a preferential attachment (nodes tend to connect with others that have high degree or "popularity is attractive" mechanism). Panel C shows the mesoscopic structure. The communities are clearly identified, and their composition is quite varied in terms of business types (shown as different colors).

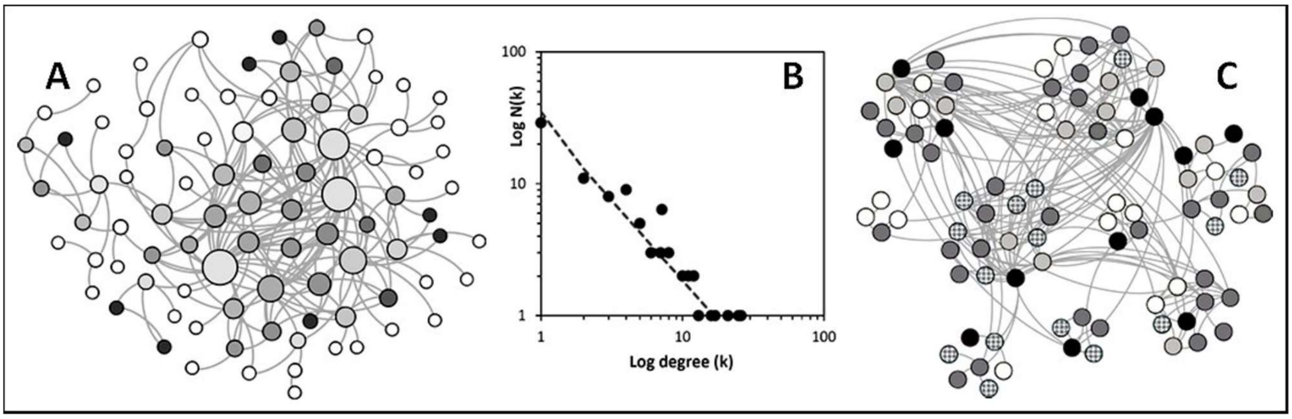

Figure 2 A tourism destination network

Although not many full studies of tourism destinations exist, some common features have begun to emerge, providing more ground for improving formation and evolutionary models (Baggio, 2020b).

Moreover, the strong connections uncovered between digital and physical entities has strengthened the idea that a smart destination is nowadays no more an option but a *conditio sine qua non* for a balanced and sustainable social and economic growth of a destination (Baggio, 2020a).

Network analysis methods have evolved rapidly in the last decade thanks to the efforts of a wide multidisciplinary community of scholars. Tourism researchers have used so far mainly the most basic techniques thus a large set of possibilities is still to be explored. Obviously, not everything done in this domain is usable and useful for tourism studies, and probably the most important challenge is that of finding, in the vast catalogue, the techniques that may be more suitable. For sure a wider collection of cases can shed better light on the similarities and differences existing in the characteristics of tourism and hospitality systems. Additionally, the methods for examining multilayer networks (those made of different layers defined on the basis of different types of elements and/or relationships) can provide more insights into questions about the components of tourism systems at various levels of organization. More importantly, longitudinal (in time) studies can help in formulating more rigorous evolutionary models, allow better understanding the formation and the development of the most relevant characteristics, and establish a more reliable basis for creating scenarios that can be of great help to inform plans, decisions and actions. Finally, more and deeper qualitative analyses can be beneficial in order to fully interpret the quantitative outcomes of the enquiries.

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