Digital Ecosystems, Complexity and Tourism Networks

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Abstract

Tourism has experienced quite relevant changes since when Information and Communication Technologies (ICTs), in all their forms, have started to permeate the society, the industry and the markets. As an effect, a new concept has gained the attention of both researchers and practitioners, that of Digital Business Ecosystem (DBE). It arises from the deep interaction between the digital world and the ensemble of individuals and organizations that compose the complex domain of tourism, and mainly for what concerns tourism destinations. Here we go beyond the known considerations on the important role of ICTs and show how the virtual and the real components are strongly coupled and co-evolve forming a single system. The conceptual framework used is that of complexity science, and, in particular, the methods of network science. These allow to well assess both, the structural and dynamic characteristics of these complex digital ecosystems. Several examples from the recent literature show how these methods have been applied so far and the validity of the outcomes, as, besides a pure academic interest, they can help in providing a deeper and better knowledge of the issues considered and can, thus, inform policy and governance activities. Moreover, the network approach allows the possibility to simulate structural changes, mainly on the virtual side, that can provide more suitable environments for improving or optimizing certain features of the system (e.g., attractiveness, innovativeness, etc.), crucial to provide a good basis for a sensible and harmonic tourism development.

Keywords

Complex systems, digital ecosystems, tourism destination, network science, structure and dynamics

Introduction

In the last fifty years, Information and Communication Technologies (ICTs) have radically changed the way we work and live mainly through the introduction and the rapid development of a digital environment, with its related technologies that have become deeply intertwined to the whole of human activities. Individuals, organizations and social structures have been profoundly impacted. New applications made widely available have had a huge influence on the very essence of social and economic structures, so that little difference is perceived today between the ‘real’ and the ‘virtual’ worlds. As Wellman envisioned some years ago (2001): computer networks have become *"inherently social networks, linking people, organizations, and knowledge",* and have fully evolved into "*social institutions that should not be studied in isolation, but as integrated into everyday lives.*"

To put it more clearly, Luciano Floridi (2015), in his *Onlife Manifesto* states that "*the ever-increasing pervasiveness of ICTs shakes established reference frameworks through the following transformations:*

i. *the blurring of the distinction between reality and virtuality;*
ii. *the blurring of the distinctions between human, machine and nature;*
iii. *the reversal from information scarcity to information abundance; and*
iv. *the shift from the primacy of entities to the primacy of interactions.*" (Floridi 2015, 7)

Floridi, in essence, states that we live in a period that can be characterized as belonging to a 'fourth (information) revolution', following those attributed to Copernicus, Darwin and Freud (Floridi 2014). The author observes that the World is populated by 'informationally embodied organisms', made of humans as well as of artificial agents, and the environment we live in, the 'infosphere', has greatly blurred the boundaries between online and offline activities and behaviors.

The basic consideration, in short, is that technology cannot be seen independent from social systems and structures. A technological system modifies the ways people act and behave providing tools and complex environments in which many activities are performed. On the other hand, it involves not only technical components, but also economic and social elements. It bases its evolution on the interplay between economic selection and social learning processes so that the continuous interactions shape all the elements interactively. In other words, in an integrated co-evolution, technology modifies social and economic relationships and behaviors and social and economic influences change the technical implementations through the use, the preferences and the requests of the users. In an ideal setting a joint optimization allows to smoothly integrate the various components and leads to the emergence of productivity and wellbeing (Cooper and Foster 1971).

Travel and tourism, as activities deeply rooted in human nature, have obviously been heavily affected by this revolution, and the very nature of the entire sector has been (and is still being) deeply modified. It is well known that ICTs and travel and tourism have established, since the beginning of their recent history, a strong relationship. The first ever industrial real-time computerized system is an airline reservation system (Sabre) and appeared already in the early 1960s. Since then ICTs, the Internet, and the Web have transformed the structure of the market, the value chains and modified the power and roles of stakeholders. The Internet age has produced a wealth of new ways for producing and distributing travel and tourism services. Web-based approaches and technologies are nowadays helping suppliers and agencies in reducing service costs and attracting customers. More importantly, these technologies generated new opportunities and threats for all those involved in the activities that, in a way or another, belong and interact with the tourism domain (Berne et al. 2012; Yuan et al. 2018; Xiang 2018). Moreover, as Werthner and Klein were noting at the very beginning of this transformation (1999): "*information technology does not only enable, but also induces changes*".

The net effect of this digital (r)evolution is that we have many more possibilities to create and sustain boundary-spanning organizational forms (Zott et al. 2010), and may increase the flexibility and efficiency of small and medium enterprises (SMEs), despite the disadvantages due to their size (Dini et al. 2008). This is particularly important in a highly fragmented and competitive domain, such as travel and tourism.

Tourism and hospitality researchers have assessed the importance and the role ICTs play in a tourism destination in many ways, also using the concept of digital ecosystem for further stressing this importance (Navío-Marco et al. 2018; Law et al. 2014; Buhalis and Law 2008; Benckendorff et al. 2019). A major question arises, however, on whether there is more than some anecdotal evidence for the importance of this role, and whether there is some indication on the type of relationship between the virtual world and the individual and organizations that compose a tourism destination. The question is important because in any complex system, as is well known, the mutual influence between structural characteristics and functional performance is very strong (Mitchell 2009; Bertuglia and Vaio 2005; Waldrop 1992; Baggio 2008).

Typically, the methods used for assessing the role of ICTs vary from surveys to the analysis of case studies towards more sophisticated econometric techniques. Here we approach the issue form a different perspective and look for clues that can provide an evaluation of the extent to which the virtual components are integrated into a tourism destination system and how they can contribute from a structural and dynamic point of view to the general dynamic behavior and, ultimately, to the 'wealth' of the entire system.

The chapter starts with a brief description of the main elements of this line of reasoning: digital business ecosystems, that are embedded in the general framework of complexity science. From a methodological point of view, the techniques of network science, especially suitable for a structural and dynamic analysis of a complex system, are used for assessing the relationship between the various components of a DBE, which is the focus of this chapter. The basic ideas and methods of network science are briefly described in the second section. The third part contains the discussion of a case involving three tourism destinations and provides support for the integration of the thesis discussed in this chapter. Concluding remarks and possible future developments close the chapter.

Complex tourism digital ecosystems

Modern ICTs evolved from a simple tool to improve the operational efficiency, to complex systems that deeply affect the very essence of business processes from a strategic point of view, so that often the design of organizations is both constrained and enriched by them (Baldwin 2012). Moreover, ICTs shape the real-time adaptive coordination both within an organization and between the organization and its network. In just fifty years, ICTs have become also a new form of mass communication, allowing exceptional possibilities to make available a wealth of materials to a wide and undifferentiated (in time and space) audience in a relatively easy and inexpensive way. Commercial and business functions have developed to a level of sophistication overcoming spatial or temporal factors so that a networked organization has become reality (Nachira 2002). This progress has made relevant (and fashionable) the concept of digital business ecosystems.

Digital ecosystems

A digital business ecosystem (DBE) was broadly characterized in the framework of an EU funded project; the definition used is (Nachira et al. 2007: 5): "*adding digital in front of Moore's (1996) business ecosystem in the Unit ICT for Business of the Directorate General Information Society of the European Commission*". In better words, (Karhu et al. 2011: 1999): "*the digital ecosystem is the technical infrastructure used to connect to the services and information over the Internet and to enable the networked transactions*", obviously including all the different stakeholders.

The analogy used is with a natural ecosystem, i.e., the community of interacting biological organisms that is embedded in a physical environment. A DBE is a complex network, comprising all the organizations that operate in order to supply certain products or services. A DBE includes a socio-economic setting with its institutional and regulatory framework (Moore 1996) completed by a technological infrastructure that forms the digital environment for the interconnected entities that supports cooperation, open innovation (Antonelli 2009; Zott et al. 2010), knowledge sharing, and their developments, new technologies and evolutionary business models (Stanley and Briscoe 2010).

DBE as complex adaptive system

A tourism destination is essentially a socio-economic network that comprises an ensemble of dynamically interacting stakeholders, jointly producing the experience for the travelers to consume (Baggio et al. 2010a). Moreover, it is an open system, continuously exchanging resources and knowledge with the environment that affects both the structure and the functioning of the system. In essence, a destination exhibits all the characteristics of a complex adaptive system (CAS). Not easy to define rigorously, a CAS is a system composed of many inhomogeneous interconnected elements, whose relationships are typically dynamic and non-linear. The actors, and, thus the system, are capable of learning and modifying their behavior and configurations in order to adapt to the environmental conditions and guarantee a balanced development. Such a system has a memory and includes feedback loops that move these adaptations in often unexpected and non-trivial ways. Continuous dynamic evolution generates an intricate mix of ordered and disordered behaviors and shows emergent phenomena, which are generally surprising, and, at times, extreme. Depending on certain conditions, the system may also exhibit a completely chaotic behavior (Bertuglia and Vaio 2005).

A tourism systems' adaptation needs to be governed and the effectiveness of the governance highly impacts the emergence and development of tourism destinations (Moscardo 2011), as it can ensure a balanced and sustainable growth, and is, therefore, fundamental for destination competitiveness. Managing and governing a complex system is notoriously a daunting task that requires a sound knowledge of the structural and dynamic characteristics of the system. This understanding can be obtained by using different methods, all based on the idea that a systemic holistic view is more suitable than traditional reductionist and partial modelling approaches; this perspective is rooted in the research tradition of what is today known as complexity science (Solomon and Shir 2003; Waldrop 1992). This approach offers several ways of understanding, thinking about and designing organizational systems, destinations in our case, that are capable of acting on and influencing their non-linear relationships. Understanding the dynamic behavior of a complex adaptive system can provide great insights and help identify key factors for change and transformation. In fact, even if individual units may be quite effective, the system as a whole may experience significant failures to respond or adapt to changes in the wider system environment. Therefore, to be effective, an organization must learn to think and act as a coherent, yet flexible entity with a high degree of communication, cooperation and collaboration in the system in which it is embedded (Merali and Allen 2011).

The dynamic complexity characteristics are also a fundamental element for the life of a socio-economic system. Conventional economic theory, in fact, often opens with the assumption that a system is in, or capable of attaining, a state of stable equilibrium. This is a notion drawn from classical physics that contrasts with the thermodynamic notion of equilibrium, which is a state of maximal disorder (Mirowski 1989). The study of such systems is then intended to reveal mechanisms (actual or designed) that can be subject to control. More precisely, the organization of a system is assumed to be so well defined that its mechanisms can be represented in sets of mathematical functions from which 'equilibrium solutions' can be deduced (Chen 2008). The problem is that systems with such well-defined properties cannot evolve, because they are so wholly interconnected and lack a sufficient degree of openness, while evolution can only occur when a system can change its structure, both in their internal configuration and in their relationship with the external environment (Foster 2005).

In a digital business ecosystem, it is possible to recognize two main components: a physical one, composed of the public and private stakeholders participating to the different e.g. tourism and hospitality activities, and its virtual complement, formed by the technological equivalents of these stakeholders, their online presences, i.e. usually a website. The two components are coupled and co-evolve, thereby are forming a single entity. The real part generates the virtual one, and we have evidence that, given the relationship between the two, all modifications, changes or perturbations originating in one of them, propagate to the whole DBE. The interactions within the combined network can be harmonized via ICTs or other traditional forms of coordination mechanism (face-to-face or technology mediated), thus, confirming the idea that the offline and online worlds should be taken into account together when analyzing a DBE (Dini et al. 2008). Actually, information systems and online applications can be considered important coordination mechanisms (Bregoli and Del Chiappa 2013) for their capacity to allow information and knowledge to flow more easily across the system (Fyall 2011). They are deemed to facilitate many processes in the realm of governance and planning (Micera et al. 2013), and enhance the interactions between stakeholders easing the sharing of information and opinions in an attempt to converge towards a common vision (Funilkul and Chutimaskul 2009).

A DBE has three main characteristics that induce several benefits to the companies and stakeholders it comprises: value logic, participant synergy and institutional stability. In such systems, ICTs allow participants to co-create value gaining, higher efficiency, flexibility, and innovation benefits (value logic) and to deliver this value effectively, thus, leveraging on their complementarity and co-evolution (synergy). The coordination ensured by legitimacy, trust and reputation in the ecosystem as a whole generates an institutional stability that, when well governed, may allow a balanced socio-economic growth (Llewellyn and Autio 2012).

The question of how to assess this relationship and its strength can be answered by resorting to the methods available for the study of a complex adaptive system (Shalizi 2006; Amaral and Ottino 2004). Among these, the techniques of network science seems especially suitable. In fact, apart from other considerations, the most distinguishing characteristic of a complex system is the ensemble of relationships, often dynamic and non-linear, that interconnect the different elements and that generate its behavior. The structure of these relationships plays a crucial role in determining the overall structure of the system and, in turn, its functional capabilities (Caldarelli 2007). For example, the study of hyperlink ensembles between the websites of many tourism destinations have provided interesting insights into the communication relations in those systems, the extent and shape of the web systems, their navigability, and the information flows across the different networks (Baggio 2007; Éber et al. 2018; Raisi et al. 2018). In fact, these studies of hyperlink networks are an important basis for the more complete empirical analysis of tourism digital ecosystems.

Studying these structures requires a special care, since the characteristics are such, that traditional statistical practices risk missing or have difficulties in explaining important features when ignoring the irreducibility of a complex entity (Levin 2003). Moreover, the separation between qualitative and quantitative methods turns out to be inappropriate, as the measurements can deliver outcomes that may be unexpected, at least from a simple intuitive view (Liu et al. 2007). This is especially true when dealing qualitatively with the overall structure or the relative importance of the different actors. In parallel, a pure quantitative analysis is unable to render the nuances of a specific situation or to explain peculiar conditions. This calls for caution in using network analysis metrics that should simply give a flavor of objectivity to purely qualitative research designs. It is, therefore, essential to combine a good and effective set of metrics with a suitable layer of qualitative interpretation for understanding what these metrics mean in the specific cases under study (Baggio 2007; Mariani and Baggio 2020; Wolstenholme 1999; Schipper and Spekkink 2015). To this extent, the use of one of the proposals in the area of mixed methods seems to be a good choice to provide effective and reliable outcomes and solve problems that cannot be solved by other (single) approaches, thus, offer better insights and allow a wider array of perspectives (Baran 2016; Truong et al. 2020).

A short reminder on network analysis

The main objective of a network study is to map and analyze the patterns of relations between the elements of a system, be it a natural, artificial, social, ecological, or economic. These systems can be modelled as sets of distinct elements or actors (the nodes or vertices of the network) connected by the relationships existing between them (the links or edges), that can also carry a weight (cost, importance, etc.) or a direction (e.g. the relationship predator-prey in a food web).

Once these components have been enumerated, a network can be built. This can be represented numerically by a NxN matrix A_G (i.e. N is the number of nodes in the network), called adjacency matrix, whose elements are $A_G(i,j)=w$ if a link between node i and node j exists, or 0 otherwise (i.e. w is the weight associated to the link, if no weights are considered w=1). This representation allows using the methods of linear algebra for expressing a wealth of metrics that account for the properties of the network.

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. da Fontoura Costa et al. 2007; Newman 2010; Barabási 2016). Here, we only recall a few concepts useful to follow the discussion.

Three levels are typically envisaged for a full network study:

- *global (macroscopic) level*: the topological structure operationalized by metrics, 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), and efficiency (capability of the system to exchange information). The most common metric for describing the global topology is the statistical distribution of the degrees (degree distribution). Its shape, in fact, signals well the general features of the network, its complex characteristics and its capacity to act in response to several dynamic processes. Many networks have been found to have a power-law distribution of the degrees, that is, they have a few nodes with many connections (i.e. the hubs) and many nodes with few links. A power-law indicates the absence of a normal, typical degree or scale (e.g. the mean of a symmetric normal distribution) hence, the name scale-free is given to networks whose degree distribution exhibits this characteristic. 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.
- *intermediate (mesoscopic) level*: the community (modular) structure, i.e. the quality of a division of the network into modules (i.e. communities) more densely connected internally than with the rest of the network. Stochastic algorithms allow identifying these clusters (Fortunato 2010). Also hierarchical structures can be detected with the help of this type of analysis.
- *individual (microscopic) level*: the nodal characteristics (degree, betweenness, closeness, clustering coefficient, etc.) that determine the relative importance of a node within the graph. The normalized version of these metrics is usually called centrality (e.g. degree centrality, betweenness centrality, etc.).

After a slow start, the application of network analytic methods to the study of tourism has seen a good interest by the academic community and many works today exist that analyze different aspects of the domain (Baggio 2017; Casanueva et al. 2016; Merinero-Rodríguez and Pulido-Fernández 2016; van der Zee and Vanneste 2015).

Dynamic processes

A DBE is an evolving dynamic system. In this regard, important processes are those that involve the capability of the actors in a network to transfer information and to synchronize their opinions. Both are fundamental processes for any effective governance activity (Jackson 2008). Productivity, innovation and growth are strongly influenced by them, and the way in which the spread occurs affects the speed by which individual actors perform and plan their future (Antonelli 2009; Baggio et al. 2010a; Cooper 2006; Ostrom 2010). Moreover, good and effective decision-making requires a good information flow and the coordination of the opinions of the parties involved (Brodbeck and Guillaume 2015). When such dynamic processes are involved, a full understanding cannot be directly inferred from the networks' properties described above. Small local changes, for example, do not modify them substantially, therefore, metrics such as degree distribution or homogeneity, clustering coefficient, average path length or degree correlations are unable to characterize the diffusion patterns (Atay et al., 2006) and we need to resort to a numerical simulation.

A commonly used way to study information spread is the one based on the analogy with the diffusion of a disease where we consider an actor as "infected", who accepts an idea or a message and is ready to transfer this information (or knowledge) to other connected actors. Thus, the population of individuals in a group are considered divided into three groups: those susceptible (S) to the infection, the infected (I) and those who recover (R) from infection when acquiring some form of immunity or become susceptible again. Different processes and the respective models are named after the type of individuals they deal with. Therefore, SI models include only susceptible or infected elements; SIS models in which individuals go through a complete cycle: susceptible, infected, then susceptible again; and SIR models that consider susceptible individuals that are infected and end their process by being removed (i.e. immunized or eliminated from the initial population) (Hethcote 2000).

Traditional epidemiological models disregard the relationships between the different individuals and consider only their statistical distribution. However, as literature has amply shown, when a network of actors and relationships is the environment in which the diffusion takes place, a number of important parameters of the process change resulting in terms of duration, spread and conditions for the diffusion as well as in outcomes that are different from those obtained in a pure no-link case. In other words, the structure of the network is highly influential in determining the basic unfolding of the process (Da Costa & Terhesiu, 2005; López-Pintado, 2008).

More precisely, in an epidemic diffusion process, the crucial parameters (i.e. those controlling the process) are the rate of birth β and the rate of extinction δ of the disease. Their ratio $\tau = \beta/\delta$ constitutes a threshold so that an epidemic exists only if $\tau < \beta/\delta$. In classical epidemic models τ is the density of susceptible individuals.

Once a social network is defined, it is possible to build a model and perform a numerical simulation for understanding the dynamic of the whole process in the context examined and, if needed or applicable, the network can be modified in order to optimize the diffusion and evaluate the effects of the modifications. Over the last years, the development and the dissemination of hardware and software instruments has promoted the growth and the use of numeric simulation models. The reliability and credibility of these numerical simulations are considered sound, provided some basic requirements are met. The most important are the choice of a rigorous conceptual model for the settings for which the simulations are run and the accuracy of the software-program used. With these conditions simulations have proved to be effective and efficient in representing different systems and processes and may, thus, be considered valuable aids in ecosystem related decision-making (Klein & Herskovitz 2005; Mollona 2008).

Besides running a complete numerical simulation, a good indicator comes from another technique: spectral analysis. A network, as said, can be represented by a square NxN matrix containing real values. When, as in our cases, the matrix is symmetric (i.e. networks are undirected) its eigenvalues are real. The set of eigenvalues is called the spectrum of the matrix and has a remarkable importance. In fact, many studies on the networks' spectra have highlighted their role in representing many properties that concern both the main static structural and dynamic properties of a network (Van Mieghem 2010).

More precisely, the largest (principal) eigenvalue of the adjacency matrix λ_N (called spectral radius) plays a crucial role in controlling the two dynamical processes of diffusion and synchronisation we are interested in. Research has established that a critical threshold τ exists, which is the condition that is linking the characteristics of the *virus* and the network topology. The threshold for an "epidemic" diffusion in an undirected graph is $\tau = 1/\lambda_N$ (Chakrabarti et al. 2008).

A similar result exists for what concerns a synchronisation phenomenon. The parameter controlling the speed and extent of the process (e.g. ideas, opinions, attitudes, etc.) K_C turns out to be: $K_C \propto 1/\lambda_N$ (Restrepo et al. 2005). Therefore, the dynamics of both processes (i.e. diffusion and synchronization) can be guessed by looking at the largest eigenvalue of the adjacency matrix: the higher its value the lower the critical thresholds, the easier it is to inform and convince the actors in a DBE network, or to synchronize their opinion and reach a consensus, i.e. the more "efficient " the process is.

In what follows, these methods are used for assessing the structural relationship between the different elements of a digital tourism ecosystem and to gauge their importance for the evolution of the DBE.

Exploring tourism digital ecosystems: a multiple case

The systems examined here are three Italian well-known destinations: Elba, Gallura, and Livigno. Elba is a Mediterranean island off the coast of Tuscany (central Italy), Gallura-Costa Smeralda is the seaside north-eastern region of Sardinia, and Livigno is a mountain district in northern Italy, close to the Swiss border. The size of the three destinations, in terms of operating tourism stakeholders, is similar, i.e. about one thousand companies. Similar is also their tourism intensity: about half a million visitors per year, with a strong seasonality. Finally, all of them can be considered mature destinations with well-established identities and a rich offer of products and services for their visitors. The networks considered here have been described elsewhere (Baggio and Del Chiappa 2014; Sainaghi and Baggio 2013; Baggio et al. 2010b). They share many common properties and structural configurations, so that it is possible to conjecture that destinations hold structurally similar, and arguably, universal characteristics. This sets an interesting basis for the design of governance strategies and for the planning of policies or activities and the design and launch of products and services (Baggio 2020). Such a conjecture can be complemented by the considerations we are making on the intricate connections between the physical and the digital components of a DBE. To do so, we analyze this connection by considering the *structural* role played by them.

For all the destinations, we consider the whole network as composed of two elements: the *real* one formed by the destination stakeholders, and the *virtual* one made of their technological representations, i.e. tourism websites.

The global topological analysis reveals a striking similarity between the real and the virtual parts. Examining the degree distributions (figure 1, adapted from Baggio & Del Chiappa, 2014) it is easy to see how well they match. A Spearman rank correlation confirms the visual impression with high significance. The values for the three correlations are: Elba = 0.92, Gallura = 0.97 and Livigno = 0.96 (in all cases p-values $< 10^{-5}$).

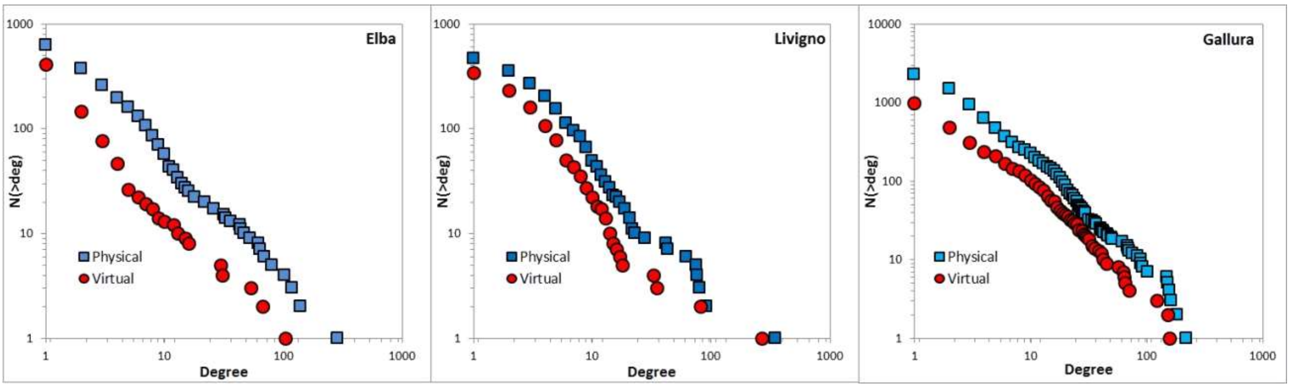

Figure 1 Cumulative degree distributions for the physical and the virtual components of the three networks

To further confirm this first result, a mesoscopic analysis was performed. The community detection algorithm chosen is the one proposed by Clauset et al. (2004), which is computationally relatively fast and, even if not endowed with a high resolution power (Fortunato and Barthélemy 2007), is quite efficient in finding coarse grained clusters, that is what is needed for a case like the one examined (Danon et al. 2005).

The analysis finds a relatively low separation between the communities uncovered: the modularity index Q is generally < 0.5 (Q is normalized so that Q=0 means no community detected, Q=1 means communities fully separated). What is important, though, is that all modules have a mixed population and the distribution of both types of elements can be assumed to be rather uniform (figure 2, from Baggio & Del Chiappa 2014). In fact, the Gini coefficient, that measures the uniformity of the ratios between real and virtual elements across all modules is < 0.2 (the coefficient is 0 for maximum uniformity, 1 for maximum inequality).

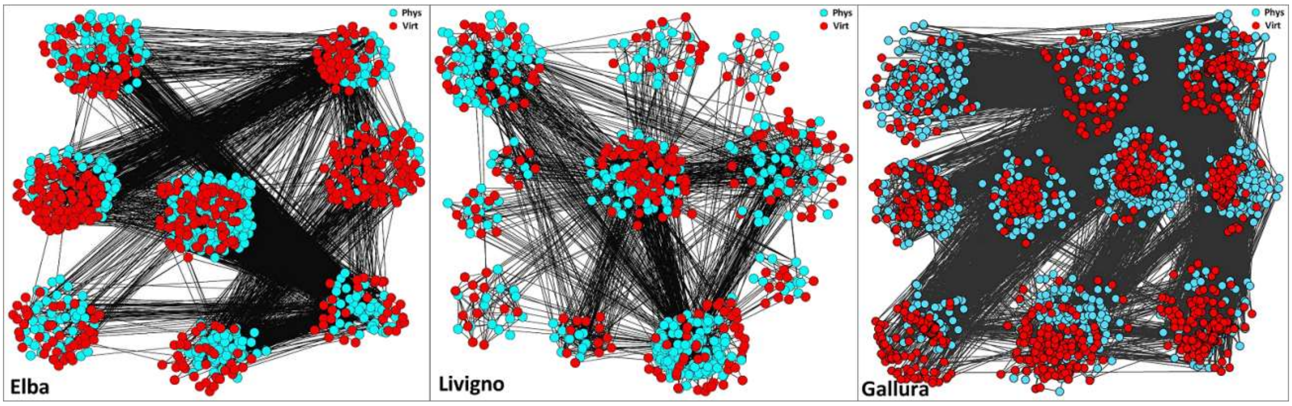

Figure 2 The communities recognized by modularity analysis. Different colours identify physical and virtual elements

A second consideration involves the dynamic properties of the three systems and analyses the processes of information diffusion and opinion synchronization. In order to have a more realistic model, we weight (i.e. attach a value w to the link) the networks considering the efforts or the costs of establishing and supporting a real or a virtual connection. We assign w=3 to links between real entities, w=2 to links between real and virtual elements and w=1 to links between virtual components. Although arbitrarily chosen, these values give a reasonable account for the differences in connecting elements of different nature. It must be noted here that, in any case, the results that follow do not change in *meaning* if different values are used, provided they take into consideration the different situations.

As described previously we carry out a spectral analysis of the three networks and use the spectral radius which is a good indicator of the "efficiency" of the processes. The results can be found in Table 1 and speak for themselves: the DBE networks, with their combined elements (real and virtual) perform definitely better than the separated components.

Table 1 $1/\lambda_N$ for all the networks examined

Destination	Weighted DBE	Real	Virtual
Elba	0.0292	0.0434	0.0899
Gallura	0.0167	0.0437	0.0503
Livigno	0.0194	0.0428	0.0776

In other words, from a structural point of view, an integrated digital ecosystem has beneficial effects on the functioning and the competitiveness of a tourism destination, besides the other known influence digital technologies may have (Law et al. 2014; Standing et al. 2014).

Concluding remarks

The word ecosystem has become a popular buzzword in the worlds of business and media and in the tourism domain as well. As said, the concept comes from ecology and denotes a community of interacting organisms and their physical environment. This meaning can well be extended to the tourism systems discussed in this contribution. However, in many cases, the term is used incorrectly. For example, expressions such as the 'Apple ecosystem' or the 'Google ecosystem' or the '…online ecosystem of …' refer to the supply or partner chains, but do not necessarily identify complex entities, such as those we have discussed so far.

A tourism destination is today, to all extent, a digital ecosystem in which all the components, no matter whether digital or physical, play a crucial role. The analysis conducted here has clearly shown that this statement is not only the result of the *impression* arising from the wide diffusion of technological tools made available in recent times, but, just for this reason, a deep structural binding exists that has also a fundamental influence on important dynamic processes.

When dealing with complex socio-economic systems the simplistic analysis based on traditional economic approaches, as said, is not sufficient for explaining all the different structural and dynamic characteristics of such systems (Foster 2005). In particular, the idea of producing models essentially grounded in the equilibrium and the rationality of self-stabilizing markets is unable to account for the mutable and often highly unpredictable configurations emerging from the nonlinear interactions typical of a complex system (Arthur 1999; Foxon et al. 2013). As remarked elsewhere, these models lack evidence in economic history (Chen 2008). The problem is that a complex ecosystem is a dissipative system, usually far form equilibrium states and strongly dependent on external influences. An evolutionary perspective, instead, provides a general framework, in which equilibrium is a special case, thus, is better suited to understand features, such as cyclic phenomena, market resilience, social movements, organizational diversity, etc. (Jackson 2008; Elsner et al. 2015).

Although tested here on only three cases, we might reasonably conjecture that this is a more general property, given the striking similarity of the topological characteristics found studying many destinations (see also: Casanueva et al. 2016; van der Zee and Vanneste 2015; Baggio and Fuchs 2018; Baggio 2017).

Modelling a destination as a network also allows using numerical simulations for the derivation of scenarios that would otherwise be difficult to evaluate. In fact, the approach makes possible to modify the structure of the existing relationships and optimize the whole system with respect to these diffusion processes. Once obtained a configuration that satisfies certain objectives, the implementation of the changes can be more easily performed on the digital component rather than on the real one. For example, as shown elsewhere (Del Chiappa and Baggio 2015), an increase in connectivity of the virtual component can provide a significant improvement in the capabilities to diffuse information or knowledge and, therefore, greatly favour the achievement of a consensus.

One more issue is important. There is a recognized imperative, for a tourism destination, to improve its attractiveness and competitiveness by fostering creative and innovative offerings. Although traditionally thought to be 'individual' traits, these have shown, in the last decades, a clear strong dependency from the environmental settings in which these 'individuals' are embedded (Baggio and Moretti 2018; Fuchs and Baggio 2017). It is reasonable to think, thus, that structural changes can be highly valuable for improving the creativity and innovativeness characteristics of a tourism system and of its stakeholders (Hjalager 2002, 2010). In fact, besides any consideration on the individual (organizations in our case) capabilities to be creative and innovative, a strand of literature on this subject has highlighted the importance of the network of relationships they have, claiming the importance of a social side of creativity (Amabile 1988; Uzzi and Spiro 2005; Perry-Smith and Shalley 2003). The ideal structure is found to be a modular structure in which densely connected communities are loosely bound to others so that a creative system can emerge from a good combination of weak network ties (Granovetter 1983) with high quality information spread (Hansen 1999), mixed with a number of strongly connected clusters able to provide a more efficient information exchange (Uzzi 1996; Fleming et al. 2007).

Having assessed these characteristics in a destination (Baggio 2014), it is possible to find the changes needed for improving the environmental settings and to ensure better conditions for favouring creativity and innovation. Here too, it is reasonable to suppose that acting on the virtual side may be easier and faster than attempting a restructuring of the relationships between the real organizations.

Expected Future Developments

It is not easy to foresee what research can provide in the future about the topics discussed here. In any case we can envision two lines of investigation.

The first one refers to a deeper examination of the relationships between the virtual worlds and the different types of tourism ecosystems, taking into account not only the connections among tourism organizations, but also those with the other elements existing in a geographical area and that often have not been fully considered in *pure* tourism research, such as transports, local populations or ecological environments.

For what concerns the methods used here, first is the obvious desire to see more similar studies, so as to strengthen the conjecture of universality set above. Then it is possible to implement simulation models that will allow better exploring the effects of different structural configurations on the general properties and the dynamic behaviors of a digital tourism ecosystem, with a focus on those elements that might improve the attractiveness and the competitiveness of a destination, or make it more resilient with respect to possible internal or external shocks, or provide a better architecture for a *smart* functioning of the system.

These considerations are even more important in this period. As known, the huge crisis connected with the pandemic COVID-19 infection has changed much of our views, attitudes and behaviors and will inexorably change them more in the future. For what concerns the information and communication technologies, the forced utilization experienced in this period as substitute of many activities will spur a new and different awareness in the general public and by tourism operators. This, as many deem, increases the need not only to better understand, but also to challenge old conceptions and proactively act for a different approach to the social, economic and technological realms to act both a short and a long-term response for the ‘revitalization’ of the whole tourism domain. In this regard, a renewed and critical reflection is needed about what technology can do and on the foundations of its basic social, economic and technical aspects. This new mindset, based on the past achievements and a call for more transparent, creative, plural and equitable approach is already being well considered (Gretzel et al. 2020). The discussion presented in this contribution goes in this direction.

Cross-References

e-Tourism: a Historic Perspective

Smart tourist

Network science

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