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Abstract

Eco-Industrial Parks (EIPs) are defined as a community of firms located in the same area and linked in a network of collaborative relationships mainly aimed at enhancing sustainability. A number of EIPs have recently spread in both developed and developing countries through diverse formation processes, resulting in different configurations. The topic has received a growing attention by the literature, even though to our knowledge the available studies lack to characterize the EIPs' organizational models and analyse how models reflect on the EIP's sustainability. The aim of this paper is to fill this gap, proposing a framework that characterizes EIPs along two dimensions related to organization and sustainability, which are further described through specific variables. We apply the framework on 28 EIPs and conduct cluster analysis to group them according to the organizational dimension. We then identify different organizational models of EIPs and discuss the possible linkages between such models and the adopted sustainability practices. The research findings have practical implications concerning policies and strategies to enhance EIPs sustainability.

Keywords: Eco-industrial parks, industrial symbiosis, organizational structure, sustainability practices, cluster analysis.

1. Introduction

Since the seminal paper of Frosch and Gallopulos (1989) an extensive body of research has flourished, leveraging on the analogies between natural and industrial ecosystems. As industrial ecosystem we mean "a community or network of companies and other organizations in a region who chose to interact by exchanging or making use of by-products and/or energy" (Gertler, 1995) so as to benefit from the systemic reduction in the use of virgin resources and in the waste to be disposed, as well as from the increase in variety and amount of outputs that have market value.

Ayres and Ayres (2002) remark that several aspects of industrial networks mimic distinctive phenomena of biological systems, such as the cycling of materials, nutrients, and energy, or the interactions among individuals playing the role of producers, consumers, or decomposers (Liwarska-Bizukojc *et al.*, 2009). According to this research stream, which is usually called industrial ecology (Allenby and Graedel, 1993; Ehrenfeld, 2004a), rather than emphasizing the independence and competitiveness of companies, studies should stress their collaborations and interdependence (Côté and Cohen-Rosenthal, 1998). These characteristics, indeed, move the focus from monadic individuals to their interconnectedness, which is considered crucial in assuring the resilience of industrial ecosystems and giving them efficiency and persistency over time (Zhu and Ruth, 2013).

Moreover, in the last decades studies on industrial ecology have been also spread due to the increasing prominence gained by the concept of sustainability: scholars and strategic consultants have stressed that greening production processes is a key factor for both single companies and local networks of firms to gain competitive advantage (Shrivastava, 1995; Tudor *et al.*, 2007). In addition, the promotion of sustainable development has been the focus of many governmental policies and international initiatives, which have been recently multiplied: in 2012, the United Nations Conference on Sustainable Development "Rio+20" reaffirmed the inter-linkages between environmental and social goals in building an economically, socially, and environmentally sustainable future (United Nations, 2012). In September 2015, the same concept drove the United Nation General Assembly in adopting the resolution "2030 Agenda for Sustainable Development", which highlights 17 sustainable development goals including sustainable production and consumption (United Nations General Assembly, 2015).

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Several researchers (Roberts, 2004; Korhonen, 2004) have pointed out that unsustainable industrial systems might turn to sustainability by borrowing from the nature the model of material recycling and energy cascading, wherein there is little or no waste. Nonetheless, the character of most of the research on industrial ecology is speculative: rather than "offering concrete solutions and practical measures for policy makers and business managers" (Korhonen, 2004) so as to promote a disruptive innovation in production processes (Hawken *et al.*, 1999), its main contribution seems to be, sadly, the mere description of materials and energy flows. Therefore, Gibbs and Deutz (2007) question whether the approach commonly adopted by scholars is effective for moving traditional industries toward the principles of industrial ecology and helping them to build synergies that mutually improve their effectiveness in a win-win scenario.

At the opposite, the concrete realization of industrial ecology principles is more frequently referred to as industrial symbiosis. Chertow (2000) defines industrial symbiosis as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of material, energy, water, and by-products". She also claims that symbiotic relationships are more complex than the usual two-side exchanges that occur between companies (Chertow, 2007): as a rule of thumb, she proposes to define as industrial symbioses only those relationships that involve at least three different actors sharing two or more different resources. According to her, the pillars that underpin the establishment of fruitful industrial symbioses are geographical proximity and the existence of a collaborative approach among business actors. Both pillars, indeed, enhance the opportunities for companies to reuse by-products, share utilities and infrastructures, and arranging a common provision of services.

Roberts (2004) stresses that "the clustering of firms with similar waste and by-product streams" let the achievement of a critical mass of waste in one location, which in turn "offers opportunities to encourage the co-location of firms that can reprocess waste material", to promote new synergies and efficiency gains and, ultimately, to create "value for individual firms and collective industry business". This is the basic intuition of eco-industrial parks (EIPs), namely industrial clusters wherein a community of firms linked in a network of collaborative relationships exploit new business opportunities so as to increase their economic performance, by minimizing the environmental impact and creating benefits for the local community (Côté and Hall, 1995; Martin *et al.*, 1996; Côté and Cohen-Rosenthal, 1998). As pointed out by Roberts (2004), industrial symbiosis can be implemented at different scales, which range from the micro-level of single plants to the macro-level of a global network of companies and regional clusters wherein the principles of circular economy are applied (Andersen, 2007; Su *et al.*, 2013). EIPs are in the middle, as they can both reach the economies of scale, which cannot be obtained at a firm-level, and take advantage of geographical proximities, which are difficult to exploit in dispersed networks.

Recently, a number of EIPs have spread in both developed and developing countries, with specific features and various degrees of success (Shi *et al.*, 2010; Sakr *et al.*, 2011; Bai *et al.*, 2014). Some of them have been promoted as governmental initiatives, whereas other ones have resulted from spontaneous processes carried out by companies (Behera *et al.*, 2012). Despite such a variety, the common driver for these initiatives is the awareness that leveraging on circulation of materials and energy may be beneficial for both the companies and the environment (Yang and Lay, 2004). Simultaneously, the topic of EIPs has received a growing attention by scholars, who slightly have moved from individual case studies and assessments of single EIP programs, to cross-country analyses of EIPs as well as of governmental policies aimed at promoting their establishment (Shi *et al.*, 2010). However, it still remains disputed whether and how the development process of an EIP and the way it is organized are somehow correlated with the sustainability features that characterize the companies that belong to that EIP as well as the EIP as a whole. Our contribution is in line with such analyses and makes a step forward. In particular, our goal is twofold. First, we aim at identifying possible organizational models of EIPs. Second, we explore possible linkages between the organizational model of an EIP and its sustainability practices.

To do this we develop a framework based on two dimensions, *i.e.* the organizational aspects of EIPs and the adopted sustainability practices. Each dimension is described by a number of variables identified from the literature. We use the framework to characterize several heterogeneous EIPs, worldwide located, along both dimensions. Then we apply cluster analysis to investigate the existence of different organizational models of EIP as well as to distinguish EIPs based on the adopted sustainability practices. Finally, we explore whether and how the organizational and sustainability dimensions are related to each other.

The framework is described in the next Section: two dimensions of analysis, and the attendant variables, will be considered (Sections 3 and 4). In Section 5 we present the set of EIPs and characterize them in accordance with the developed framework. By adopting the cluster analysis methodology, these EIPs are grouped with reference to each dimension so as to identify specific organizational models and investigate the relationships among the two dimensions (Section 6). Finally, Section 7 discusses results and limitations as well as suggests avenues for further research.

2. Framework

To address the goal of this paper, a framework to investigate the features of EIPs is proposed, based on an extensive literature review on EIPs and related concepts, such as industrial ecology and industrial symbiosis. Peer-review scientific journals with management focus have been scrutinized and features that describe EIPs identified. The framework, which is extensively presented in the following Sections, is composed by two dimensions, namely organizational and sustainability, which seem to be the more relevant to be investigated: on the one hand, the organizational dimension emphasizes the fact that EIPs are clusters of firms, on the other hand, the sustainability dimension reflects the ecological and responsible peculiarities of such clusters of firms (EIPs). For each dimension, a number of variable are provided, each related to a peculiar aspect of EIPs.

The former dimension investigates the organizational structure and uses nine variables to describe how EIP have been developed and how they are managed. Specifically, this dimension scrutinizes whether the EIP has emerged spontaneously or has been intentionally promoted by an initiator, if there exist an anchor tenant playing an agglomerating role within the EIP, and if the EIP leverages on governmental support. To characterize the organizational structure of EIPs, heterogeneity of companies that participate to the EIP is also considered, as well as the existence of cooperation with external subjects, such as companies, research centres, and governmental agencies. Other variables within this dimension explore the existence of shared information systems and the commonality of support services among the EIP actors.

The latter dimension relates to features and initiatives that are adopted within EIPs as for sustainability, and covers both the environmental and the social fields. The former is described by means of eight variables: four of them – *i.e.* the existence of by-products exchange, the sustainable use of natural resources, the adoption of Best Available Techniques (BATs), and the eco-design – relate to the production processes adopted within the EIP, whereas other four variables – *i.e.* prominence of green procurement, the existence of sustainable transportation management for both people and goods, the attention devoted to landscape protection, and the environmental compliance – relate to the management practices. On the other hand, the social field is investigated with reference to the existence of social welfare services, the training and education initiatives, the community awareness and participation, and the product responsibility.

Both dimensions, and attendant variables, are listed in Table 1. In the following sections, each variable is described and positioned in the literature.

Table 1. Dimensions and attendant variables and values included in the framework.

Dimension	Variable (values)
Organizational	– Development process (top-down *vs.* bottom-up) – Existence of an anchor tenant (yes *vs.* no) – Governmental support (yes *vs.* no) – Heterogeneity (high *vs.* low) – Cooperation among companies (yes *vs.* no) – Cooperation with universities and research centres (yes *vs.* no) – Cooperation with governmental agencies (yes *vs.* no) – Shared information system (yes *vs.* no) – Shared support services (yes *vs.* no)
Sustainability	– By-products exchange (yes *vs.* no) – Sustainable use of natural resources (yes *vs.* no) – Adoption of best available techniques (yes *vs.* no) – Eco-design (yes *vs.* no) – Green procurement (yes *vs.* no) – Sustainable transportation management(yes *vs.* no) – Landscape protection (yes *vs.* no) – Environmental compliance (yes *vs.* no) – Social welfare services (yes *vs.* no) – Training and education (yes *vs.* no) – Community awareness and participation (yes *vs.* no) – Product responsibility (yes *vs.* no)

3. Organizational dimension

3.1. Development process

The literature mentions two main models of development process for EIPs. On the one hand, Chertow (2007) discusses the self-organizing symbiosis, which is typical of EIPs arising from a spontaneous initiative of companies willing to achieve efficiency, cut costs, or expand its business by leveraging on resource exchange with other organizations. In other terms, the intuition that promoting symbiosis among companies is beneficial for all the parties involved makes the EIP unintendedly emerge from the gradual agglomeration of companies mutually linked by symbiotic relationships (Baas and Boons, 2004). The spontaneous development of EIPs based on companies acting on their behalf mimics the way natural ecosystems arise: such a model is in fact considered the most frequent (Chertow, 2000; Jacobsen, 2006) and successful (Heeres *et al.*, 2004; Gibbs and Deutz, 2007).

On the other hand, the development of EIPs can stem from an exogenous promoter, called initiator (Brand and de Bruijn, 1999). This can be a government agency (typically at a national or regional level), as well as an association of companies or entrepreneurs, a trade union, a chamber of commerce, or another player acting as institution *de facto* (Heeres *et al.*, 2004). In some cases, the role of the initiator is to promote demonstration programs, what are called 'designed' symbiosis networks (Behera *et al.*, 2012). More frequently, the external stimulus for exogenously planning the development of an EIP can be the need to compel with stricter environmental regulations (Korhonen and Snäkin, 2005), reduce waste or pollution (Desrochers, 2004), reconvert abandoned industrial estates (Tudor *et al.*, 2007), or support companies located in a given area in facing toward competitors from abroad (Seuring, 2001).

The metaphor of natural ecosystems seems more consistent with the spontaneous development of EIPs, nonetheless the case of an initiator is not necessarily in contrast with it: it has been claimed that the existence of a promoter aims at overcoming market failures, which otherwise would impel the development of symbioses among business actors (Tudor *et al.*, 2007). By contrast, several analyses (*e.g.* Heeres *et al.*, 2004; Gibbs *et al.*, 2005; Chertow, 2007) on projects funded in 1996 within the U.S. President Council of Sustainable Development have shown that EIPs arisen through deliberate planning suffer from a low success rate. Nonetheless, some positive exceptions exist, mostly located in the Far East countries, wherein the governmental role in driving economics is prominent (Zhu *et al.*, 2007; Zhang *et al.*, 2010; Behera *et al.*, 2012).

3.2. Existence of an anchor tenant

Often a major company located in a specific area, heavily committed in R&D activities, and having at least a partial absorptive capacity in a given technological area (Agrawal and Cockburn, 2002) plays a key role in promoting the emergence of self-organizing enterprise networks and, specifically, in sustaining the establishment of an EIP. Scholars in the field of regional studies define such an organization as anchor tenant (*e.g.* Lowe, 1997; Côté and Cohen-Rosenthal, 1998; Chertow, 1998; Korhonen, 2001; Heeres *et al.*, 2004) or, less frequently, as magnet (Tudor *et al.*, 2007) or initiator (Brand and de Bruijn, 1999).

As the anchor tenant is a major manufacturer, it can provide the EIP with a continuous waste stream that can be potentially used by third parties in their manufacturing processes. It may be also able to turn information about the existence of some waste materials or by-products into business opportunities. Furthermore, thanks to its reputation and capability (Lowe, 1997), the anchor tenant has many linkages with several satellite enterprises involved in treating wastes and supporting its production processes (Côté and Cohen-Rosenthal, 1998); therefore, it contributes to the EIP development by allowing new companies to arise or existing ones to move into the park. Finally, Behera *et al.* (2012) point out that the anchor tenant may drive the development process of an EIP also by recruiting potential partners through a formal selection process.

Sometimes, the anchor tenant's role in driving the development of the EIP is, at least partially, addressed by an incubator. This is an entity, often formally established among institutional actors and companies involved in the EIP, whose aim is to nurture the launch of start-ups, and assist them.

3.3. Governmental support

There is a general consensus on the key role of institutions in favouring an EIP growth and success (Park *et al.*, 2008), at least in combination with companies' proactivity (Heeres *et al.*, 2004). Often, bureaucracy is a strong obstacle for companies in arranging exchanges of by-products to build industrial symbioses. This is why policies should be designed so as to provide political, coordinative, educational, and infrastructural support to EIPs (Chertow, 2007; Gibbs and Deutz, 2007; Taddeo *et al.*, 2012). Liu *et al.* (2012) stress that, even when the EIP arises from the initiative of companies, government is crucial in breaking the sectorial boundaries, thus allowing the network to evolve in a regional cross-industry ecosystem. In some specific cases, the support offered by government includes the provision of suitable infrastructures (Park *et al.*, 2008), the design of appropriate coordination mechanisms to encourage companies in managing waste streams (Brent *et al.*, 2008), the dictation of prices for specific items or materials (Zhu *et al.*, 2007), or the rewarding of individual actions that generate environmental benefits (Shi *et al.*, 2010). In addition to the above possible specific initiatives, the governmental support usually involves direct or indirect subsidies to the companies that take part to the EIP development.

In their extensive review, Jiao and Boons (2014) scrutinize the governmental policies to promote industrial symbiosis and assert that it is often difficult to distinguish whether these policies have been the triggering factor for the EIP development or simply nurtured it. Moreover, they outline that the implemented programs and their evolution over time are country-specific, and observe that the nature of their impact, and specifically their effectiveness, differs on a case-by-case basis: as a guideline for policy makers, they thus emphasize the importance of taking the specific context into account.

3.4. Heterogeneity

Some EIPs include companies involved in diverse industries, whereas other EIPs seem to be more focused on a single sector. This feature of the EIP is usually called diversity (*e.g.* in Côté and Smolenaars, 1997) or heterogeneity (*e.g.* in Taddeo *et al.*, 2012). According to the technical memorandum by Martin *et al.* (1996), heterogeneity is considered key to distinguish an EIP from other kinds of businesses aggregations.

Heterogeneity may also involve the kinds of materials that flow among the companies within the EIP. According to Pellenbarg (2002), the existence of complementary materials may improve the chances of success, whereas Cohen-Rosenthal (2004) stresses the need to examine all the material flows. Sterr and Ott (2004) argue that heterogeneity and the attendant redundancy in input-output relationships may facilitate the establishment of symbiotic transactions within an industrial site. In fact, several case studies (*e.g.* Veiga and Magrini, 2009; Shi *et al.* 2010; Sakr *et al.*, 2011; Behera *et al.*, 2012) show that successful EIPs have intrinsic heterogeneity. At the opposite, a low level of diversity among firms in an EIP reduces the variety of material exchanges, and the dependency on few material or energy flows may cause instability of the park (Côté and Smolenaars, 1997).

3.5. Cooperation

As in other forms of businesses aggregations, cooperation in EIPs occurs through the network of collaborations. These include linkages among the companies that are part in the EIP, as well as collaborations with universities and research centres or with governmental agencies.

Collaborations among companies that belong to the EIP go beyond the traditional dyadic (*e.g.* buyer-supplier) relationships. Typically, they may reinforced of the existence by-products exchanges, but cannot be entirely explained by mass flow consideration (Cohen-Rosenthal, 2000): rather, they primarily grounds on people’s interactions (Hoffman, 2003), which are based on mutual trust and other social factors, which include embeddedness, proximity, openness, shared culture ad similar mind-set, among the others (Walls and Paquin, 2015). According to Gibbs and Deutz (2007), trust and cooperative relations among EIP tenants are crucial in the early phases because they reduce “the mental distance among companies” and promote the necessary cultural change.

Cooperation can also occur in form of interactions that trespass the boundaries of EIPs. For instance, a company within the EIP usually collaborates with several business entities, such as suppliers or customers, which do not belong to the EIP. Moreover, often it exchanges information with universities and research centres, which for instance provide knowledge on the possible use of by-products. Other kinds of relationships occur between companies belonging to the EIP and governmental agencies. Finally single companies as well as the EIP as a whole may have relationships with institutions, local communities, environmentalists, labour representatives, as well as other stakeholders interested in shaping the development of the park. Heeres *et al.* (2004) include the stakeholders’ engagement and their active participation among the success factors for EIPs.

3.6. Shared information system

Sharing information is a premise for the effective integration among an EIP's companies. This could be the case of kind, amount, timeliness, quality, and other characteristics of wastes and by-products generated by a company, as well as of its energy needs. The existence of an EIP implies monitoring and managing also data which are inherent to the EIP as a whole rather than directly associated with a specific company (*e.g.* air pollution, traffic, etc.): the knowledge of these data, indeed, let companies to better arrange their needs by exploiting symbioses and identify possible room for improving performance. Schwarz and Steininger (1997) define the role of waste agencies as facilitators to keep companies in touch and spread information. Also Heeres *et al.* (2004) and Tudor *et al.* (2007) stress the importance of gathering information for an EIP: according to them, key issues include products manufactured and services provided, material and energy streams, actual and potential markets, purchases, companies' resources and capabilities, their future plans, collaborations, and needs.

Finally, Milchram and Hasler (2002), in their empirical study on Austrian and German EIPs, while stressing the central role of mutual trust to impelling information transfer among recycling companies, also state that by implementing a central agency it is possible to institutionalize the knowledge sharing and the intellectual capital creation within the EIP.

3.7. Shared support services

EIP tenants may share a variety of support services, which range from basic utilities (such as security, maintenance, or transportation) to more complex ones, *e.g.* energy management, waste treatment, or regulatory/legal consulting support. Schwarz and Steininger (1997) postulate the existence of waste agencies should be also intended to offer coordination services below actual costs. Chertow *et al.* (2007) identify the existence of such common services as one of the three basic types of symbiotic transactions occurring in EIPs, the other ones being the exchange of by-products and the cooperation in training and sustainability planning. According to Heeres *et al.* (2004), the management of common services is a pre-requisite for other initiatives in an EIP.

4. Sustainability dimension

4.1. By-products exchange

To develop an industrial symbiosis it is required that two or more companies exchange by-products (Park and Behera, 2014). By-products can be solid waste, energy, water, or air: in default of symbiosis, companies would dispose them, typically upon payment, in change of some environmental cost. At the opposite, when symbiosis occurs, the company producing such by-products can give them, for free or upon payment, to another company that is able to use them as raw materials or, more generally, as factors of production. The occurrence of by-products exchange opens room for savings in favour of both involved parties: this is why this mechanism is considered the "kernel" of EIPs (Chertow, 2007).

Several scholars have described the nature of the by-products exchanges that occur in EIPs, as well as the attendant benefits, under both the economic and environmental perspective. For instance, with reference to the South-Korean EIP in Ulsan, Behera *et al.* (2012) enumerate 40 symbiotic relationships, that cover a wide spectrum of material and energy exchanges, ranging from recycling of waste oil to incineration of industrial or municipal waste supplying steam, from reuse of waste aluminium chips to conversion of high strength ammonia containing wastewater to a nutrient for microorganisms. Shi *et al.* (2010) address the TEDA EIP in Tianjin (China), isolating 81 symbiotic exchanges: 33 of them among companies located within the boundaries of the EIP, and 48 involving both internal companies and other ones not belonging to the park. Most of these transactions relate to materials, but there are several occurrences of symbiotic exchanges for water and energy. Similar results have emerged in Liwarska-Bizukojc *et al.* (2009), who analysed the EIPs in Hartberg (Austria) and Schkopau (Germany).

4.2. Sustainable use of natural resources

This variable mainly relates to the quantity and the quality of natural resources involved in the production processes of the EIP. Within the scope of this assessment, natural resources are defined as: (i) non-renewable or slowly renewable resources that are available in nature in a limited amount compared to the present and future demand (*e.g.* forest, oil, fish stocks, minerals, rare-earth elements), and are adopted in the production processes of any of the EIP actors; (ii) resources that can be directly or indirectly derived from any of the previous ones (*e.g.* energy, wood, plastics); and (iii) environmental compartments (*e.g.* air, soil, fertile ground, water basins) adopted as sinks to absorb emissions and dispose waste generated in the EIP processes. To measure the economic and environmental performance of industrial symbiosis in an EIP, Park and Behera (2014) propose an indicator based on the concept of eco-efficiency, namely the ratio between the product or service value and the environmental influence (Verfaillie and Bidwell, 2000). The latter is evaluated as weighted sum of raw material consumption, energy consumption and carbon dioxide emission.

4.3. Adoption of best available techniques

Best available techniques (BATs) are "the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole" (IPPC, 1996). Other organizations and country-specific laws and guidelines provide similar definitions of BATs (*e.g.* the 2001 UNEP Stockholm Convention on Persistent Organic Pollutants – UNEP, 2001), either referred to their general meaning or related to specific contexts. In determining BATs, multiple aspects should be considered, which include the consumption of natural resources, the use of less hazardous substances, the adoption of technologies able to minimize the amount and the dangerousness of waste and emissions, as well as to further recovery and recycling of wastes produced in other processes, and the prevention of accidents. Some attempts to manage BATs in an industrial symbiosis perspective have been adopted in some EIPs, especially located in the Northern Europe (Lehtoranta *et al.*, 2011).

4.4. Eco-design

To comply with the sustainability goals, companies located in an EIP should design their products and services so as to reduce the attendant environmental impact along their entire life cycle. This principle can be adopted by adopting techniques and methodologies such as life cycle assessment (LCA) (Guinée and Heijungs, 2005), green option matrix (Dangelico and Pontrandolfo, 2010), design for disassembly (Bogue, 2007).

Mirata and Emtairah (2005) argue that, by establishing industrial symbioses, companies are oriented toward a collective definition of problems, promote an environmentally-oriented culture of inter-organizational collaboration and foster environmental innovation. Mattila *et al.* (2010) use LCA approaches to quantify the environmental impact of a Finnish forest industrial symbiosis and suggest priorities to make processes more sustainable. Liu *et al.* (2011) adopt LCA to assess the impact of an EIP in the Shanghai area.

4.5. Green procurement

According to the Commission of the European Community, green procurement is the procurement of "goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured" (CEC, 2008). Several guidelines exist to promote public procurement practices that take into account sustainability issues, in the European Union as well as in the USA (EPA, 1999). More recently, similar initiatives have been extended to companies and business organizations for specific sectors: Uttam *et al.* (2012) analyse the ties between green procurement and environmental impact assessment in the construction sector. Routroy and Pradhan (2011) provide a framework for green procurement in manufacturing. Blome *et al.* (2014) investigate the impact of green procurement on supplier performance and show that the adoption of green procurement practices drives green supplier development, as previously stated by Bai and Sarkis (2010), and that it is a pillar for green supply chain management. Similar result emerge from the study conducted by Diabat and Govindan (2011), who developed an interpretive structured model framework to identify antecedents of green supply chain management, as defined by Srivastava (2007), and validate results on an Indian manufacturing company. With respect to the Japanese Eco-Towns program, a public initiative by which the government aimed at simultaneously achieve economic stimulation and resolve waste management issues by moving manufacturing companies toward the zero-emission concept (Ohnishi *et al.*, 2012), green procurement policies were explicitly promoted and mentioned as enabling factors to support the program and simultaneously achieve the goals of industry modernization and environmental remediation.

4.6. *Sustainable transportation management*

Designing and implementing a sustainable transportation management system within the EIP requires both people and material flows to be taken into account and efficiently managed.

Companies belonging to an EIP are typically interested in three types of material flows, *i.e.* incoming (*e.g.* for raw materials and components), outgoing (*e.g.* for finished products and wastes to be disposed outside the park), and internal (*e.g.* flows of products, by-products, and waste materials that are processed by other companies within the EIP). To arrange these flows and make them more efficient, effective, and sustainable, various initiatives can be pursued in an EIP, such as building a shared transportation management system that coordinates the disperse transportation demand of the companies (Côte and Cohen-Rosenthal, 1998) and leverages on freight consolidation (Bellantuono *et al.*, 2014), or promoting the adoption of intermodality (Tudor *et al.*, 2007), so as to increase the adoption of means of transportation having a lower environmental impact.

Sustainability can also be pursued leveraging on the transportation of people, especially with regard to the journey to work (Tudor *et al.*, 2007). Focusing on the EIP level rather than the single plant level, substantial economies of scale can be achieved, given that specific actions may require to build infrastructures for mass transportation means (*e.g.* a railway station) or sustainable transportation (*e.g.* bike lanes and tracks). Nonetheless, in most cases the impact of the home-work transportation can be dramatically reduced also if the companies belonging to the EIP adopt initiatives that leverage only on people's behaviour, *e.g.* by subsidizing mass transportation networks (*e.g.* bus lanes within the park or between it and the nearest cities), arranging a car pooling management system (Côté and Liu, 2016), granting workers that switch to more sustainable means of transportation, or imposing fees for the private vehicle entrance in the park area.

4.7. *Landscape protection*

Landscape protection is the combination of actions and initiatives aimed at preserving the natural environment and favouring the integration of human activities with it. The United Nations Environment Programme, in its technical report on industrial estates (Francis and Erkman, 2001), indicates the establishment of landscaping plans as crucial in designing new industrial parks and reconverting existing ones. The concept is relevant especially for EIPs, which are characterized by strong leanings toward the environment.

Based on the Forman's (1999) postulate of the existence of a dynamic relationship between landscape structure (namely the arrangement of natural and urban elements) and landscape function (namely the ecological flows and processes), landscape protection is not a mere attempt to disguise plants so as to not deface the natural landscape. Focusing on an EIP's design, Yang and Lay (2004) suggest to adopt the landscape ecology principles to reduce the negative ecological effects of urban and industrial development. Similarily, Anyanwu and Kanu (2006) seek to encourage landscaping to both reduce the energy needs of EIPs and contribute to absorb greenhouse gas. If the EIP is the evolution of previously existing industrial park, which was built neglecting the environmental issues, it becomes key the definition of some targeted initiatives for restoring, at least partially, the natural ecosystem, which can be named as landscape regeneration (Alexandrescu, 2016), brownfield remediation (Rizzo *et al.*, 2016) or restoration (Hartley *et al.*, 2012).

4.8. *Environmental compliance*

In most countries and for many industries, companies must comply with laws and regulations on emissions and pollution control, waste management, and other environmental issues. Beyond these impelling duties, companies may voluntarily adhere to standards, such as ISO14001 or EMAS (Eco-Management Audit Scheme), irrespective of their location in developing (Shi *et al.*, 2010) or developed (Taddeo *et al.*, 2012) countries. These schemes help companies in building a comprehensive environmental management system that explicitly indicates goals, milestones, procedures, and processes to be followed, as well as who is responsible for their fulfilment.

4.9. *Social welfare services*

To increase the workers welfare, several services that strongly impact on their quality of life – *e.g.* canteen, nurseries, sport and recreational facilities, ambulatory, tax consultancy offices – can be provided by companies within an EIP jointly, with a lower effort, and at more favourable conditions (*e.g.* lower prices or even for free). Often, the access to the above services is not restricted to workers of the companies that are located in the EIP, but is allowed – at the same conditions as for workers, or at less favourable conditions – to the workforce's relatives or possibly the population living nearby. These social welfare services (Khodakarami *et al.*, 2014) reinforce the positive externalities of EIP.

4.10. Training and education

Companies in an EIP can jointly manage human resource training on sustainability topics that are not company-specific, such as health and safety or environmental protection. Beside the economy of scale assured by centralizing the training activities at the park rather than the company level (Roberts, 2004), the aim of these initiatives is twofold: (i) they contribute to spread knowledge among workers about the importance of a sustainable behaviour; (ii) they promote a shared culture, a common language, and similar abilities. These initiatives strengthen the ties between companies, favour their mutual collaborations, and foster the development of new strategies (Côte and Cohen-Rosenthal, 1998). Lambert and Boons (2002), who shape a social science framework to scrutinize local industrial ecology, stress the importance of learning processes.

4.11. Community awareness and participation

There is a common belief that companies dealing with waste, scraps, by-products, and recycling are a source of problem for local communities, rather than an opportunity (Taddeo *et al.*, 2012): often communities, concerned about the possible effects on health and environment, are reluctant to the establishment of an EIP in their surroundings. Therefore, a change in the community view is beneficial for the establishment of an EIP (Roberts, 2004). The creation of a suitable cultural background among stakeholders is crucial especially in countries wherein citizen activists and non-governmental organizations can effectively affect the strategic planning process of companies and institutions.

To bring about such a background, and in general to build good public relations (Pellenbarg, 2002), the EIP should enhance the community awareness on the EIPs principles and benefits by promoting initiatives aimed at disseminating information locally (Lowe, 1997; Shi *et al.*, 2010) and stimulating the stakeholder involvement (Bellantuono *et al.*, 2016). Heeres *et al.* (2004), conducting a cross-country analysis of Dutch and US EIPs, show that whereas in the Netherlands the EIP development is mainly rooted on the involvement industrial and institutional stakeholders (*i.e.* companies, companies' associations, and public institutions), in the USA the development of the EIPs often implies a role also for the local residents as well as for labour and environmental non-governmental organizations. EIPs may also benefit from the participation of the local community also after they have stablished.

Possible initiatives to strengthen the ties with the local community include seminars, meetings, workshops, and educational programs for schoolchildren or students. The community participation is crucial, especially in building a climate of trust and collaboration. Nonetheless, Mirata and Emtairah (2005) highlight that local community may also play a role at an operational level. In fact, they can provide material flows to fuel the EIP companies (*e.g.* waste) or express demand for outcomes (*e.g.* heating): so doing, the community involvement is also strategic for the effectiveness of the EIP.

In most cases to capture the true needs and worries of local communities and provide them with convincing answers, ad-hoc agencies are established within the EIP (Ashton, 2009), possibly embracing also institutions, present and perspective companies involved in the EIP, and representative of the local community (Taddeo *et al.*, 2012).

4.12. Product responsibility

Ensuring product responsibility overall requires to pay attention to all the product life-cycle phases: effective design, including the choice of materials and suppliers, quality of production processes, including inventory management and transportation, usage safety, and environmental friendly disposal. It implies complementary activities as well, such as provision of clear labels and accurate instructions for use, and responsible advertising. All these activities are intended to improve the customers' health and safety and reduce the gap between their expectations and the true features of products.

The aforementioned aspects relate to single products and are typically dealt with at the single company level. Being part of an EIP allows companies to more effectively work at harmonizing their product responsibility programs and goals (Hussen, 2012), which in turn is key to exploit the intimate linkage between the firms' commitment to achieve eco-effectiveness and their enduring success (Dillon, 1994).

Table 2. List of the EIPs and their attendant descriptive features.

Name	**Location**	**Year of constitution**	**References**
Hartberg Eco Park	Hartberg, Austria	1997	Baldwin *et al.* (2004); Liwarska-Bizukojic *et al.* (2009); Caroli *et al.* (2015);
Kalundborg	Copenhagen, Denmark	1972	Chertow (2000); Baldwin *et al.* (2004); Jacobsen (2006); Caroli *et al.* (2015);
Rantasalmi	Finland	2005	Saikku (2006)
Uimaharju	Eno, Finland	1992	Saikku (2006); Korhonen and Snäkin (2005)
Arbois Mediterranée	Aix-en-Provence, France	1991	Garnier (2005); Garnier and Zimmermann (2006)
Artois-Flandres	Nord-Pas de Calais, France	1967	Van Der Kaa *et al.* (2011)
Plaine de l'Ain	Lyon, France	1974	Gibbs and Deutz (2007)
Value Park	Schkopau, Germany	1998	Liwarska-Bizukojic *et al.* (2009); Caroli *et al.* (2015)
Crewe Business Park	Cheshire County, UK	1986	Gibbs and Deutz (2007); Caroli *et al.* (2015)
Torino Environmental Park	Turin, Italy	1996	Gibbs and Deutz (2007); Caroli *et al.* (2015)
National Industrial Symbiosis Programme (NISP)	various places, UK	2005	Agarwal and Strachan (2007); Desrochers (2001)
Lopez Soriano	Zaragoza, Spain	2002	Blázquez (2008); Logroño (2010)
Vreten Park	Stockholm, Sweden	1996	Gibbs and Deutz (2007); Caroli *et al.* (2015)
Burnside	Halifax, Nova Scotia, Canada	1992	Côté and Hall (1995); Côté and Cohen-Rosenthal (1998)
Innovista	Hinton, Canada	2009	Maes *et al.* (2011)
Brownsville	Brownsville, TX, USA	1994	Lowe (1997); Heeres *et al.* (2004)
Cape Charles	Northampton County, VA, USA	1994	Heeres *et al.* (2004)
Devens	Boston, MS, USA	2005	Baldwin *et al.* (2004)
La Cantábrica	Moron, Argentina	2000	Briano *et al.* (2003); Errandonea (2000); Giacone (2003)
Paracambi	RJMA, Brazil	2006	Veiga and Magrini (2009)
Santa Cruz	Rio de Janeiro, Brazil	2002	Veiga and Magrini (2009)
Guitang	Guangxi, China	2001	Zhu *et al.* (2007)
Nanning Sugar Co	Yongning and Wuming County, China	1997	Ehrenfeld (2004a; 2004b); Yang and Feng (2008)
TEDA	Tianjin, China	1996	Shi *et al.* (2010), Yu *et al.* (2014)
EBARA Corporation	Fujisawa, Japan	2000	Côté and Cohen-Rosenthal (1998); Chertow (2000); Morikawa (2000)
Kokubo	Japan	1994	Mihashi (1998); Morikawa (2000)
Naroda	Ahmedabad, India	1998	Lowe (2001); Singhal and Kapur (2002); Bain *et al.* (2010); Rao and Patil (2015)
Kwinana	Western Australia	1991	van Beers *et al.* (2005)

5. Characterizing EIPs through the proposed framework

We applied the framework on a set of 28 well-known EIPs, selected among the ones most cited in the literature (*e.g.* Gibbs *et al*., 2005; Shi *et al*., 2012a; 2012b). The resulting set includes EIPs variously located around the world: 13 of them are in Europe, more specifically four in Scandinavian countries (Denmark, Finland and Sweden), two in UK, five in Central Europe (Austria, France, and Germany), and two in Southern Europe (Italy and Spain). Other five EIPs are located in North America (two in Canada and three in the United States), three in South America, six in Asia (three in China, two in Japan, and one in India), and one in Australia. Table 2 lists the EIPs included in the set and lists the main references adopted for the analysis.

On each selected EIP we gathered information so as obtain an accurate characterization of the park. In particular, we described every park in terms of governance and key actors, represented sectors, organizational relationships, and technological infrastructure. Similarly, we investigated the sustainability practices implemented by the firms in the EIP.

As a result, we assessed each variable included in the proposed framework along both organizational and sustainability dimensions. The analysis has been based on peer-review literature (as reported in Table 2), and complemented with information retrieved by the EIPs' website and other sources (*e.g.* technical reports). Tables 3 and 4, respectively related to the organizational and sustainability dimensions, show the application of the framework to the analysed EIPs. It emerges that EIPs differ among each other for a number of variables, both in terms of organizational and sustainability dimensions. We investigate whether any pattern exists behind the above heterogeneity. In particular, we are interested in identifying possible different organizational models of EIPs and characterize them through the adopted sustainability practices. To this end we adopt cluster analysis.

Table 3. EIPs characterization according to the organizational dimension.

Organizational dimension	Hartberg	Kalundborg	Rantasalmi	Uimaharju	Arbois Mediterranée	Artois-Flandres	Plaine de l'Ain	Value Park	Crewe Business Park	Torino Environmental Park	NISP	Lopez Soriano	Vreten	Burnside	Innovista	Brownsville	Cape Charles	Devens	La Cantábrica	Paracambi	Santa Cruz	Guitang	Nanning Sugar Co	TEDA	EBARA Corporation	Kokubo	Naroda	Kwinana
[top-down] development process					✓	✓	✓		✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓			✓			✓	✓
Existence of an anchor tenant	✓		✓		✓	✓	✓	✓	✓			✓			✓			✓			✓							
Governmental support		✓	✓		✓	✓			✓		✓		✓	✓	✓			✓	✓	✓		✓	✓	✓				
[high] heterogeneity		✓		✓			✓		✓		✓		✓	✓	✓			✓	✓	✓	✓	✓		✓			✓	✓
Cooperation among companies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Cooperation with universities and research centres	✓	✓			✓			✓	✓	✓				✓					✓	✓		✓		✓	✓			
Cooperation with governmental agencies		✓			✓	✓	✓		✓	✓	✓			✓	✓	✓		✓			✓	✓		✓				✓
Shared information system							✓	✓		✓		✓				✓				✓								✓
Shared support services	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	

Table 4. EIPs characterization according to the sustainability dimension.

Sustainability dimension	Hartberg	Kalundborg	Rantasalmi	Uimaharju	Arbois Mediterranée	Artois-Flandres	Plaine de l'Ain	Value Park	Crewe Business Park	Torino Environmental Park	NISP	Lopez Soriano	Vreten	Burnside	Innovista	Brownsville	Cape Charles	Devens	La Cantábrica	Paracambi	Santa Cruz	Guitang	Nanning Sugar Co	TEDA	EBARA Corporation	Kokubo	Naroda	Kwinana
By-products exchange	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓
Sustainable use of natural resources	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Adoption of best available techniques	✓	✓			✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓		✓	✓
Eco-design			✓			✓	✓	✓		✓				✓	✓			✓		✓	✓			✓				
Green procurement						✓	✓			✓	✓				✓						✓			✓				
Sustainable transportation management		✓				✓	✓	✓		✓	✓	✓	✓		✓			✓			✓				✓	✓		
Landscape protection			✓	✓		✓	✓	✓	✓	✓				✓	✓		✓	✓	✓	✓	✓				✓			✓
Environmental compliance	✓		✓		✓	✓	✓	✓	✓	✓		✓	✓	✓				✓		✓	✓	✓	✓	✓				✓
Social welfare services	✓		✓			✓	✓					✓		✓	✓			✓	✓	✓	✓		✓		✓			✓
Training and education	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓			✓		
Community awareness and participation	✓		✓		✓			✓	✓	✓		✓		✓	✓			✓	✓			✓			✓			
Product responsibility			✓							✓				✓				✓		✓	✓							

6. Cluster analysis

Cluster analysis is a family of techniques that use algorithms based on the concepts of similarity and dissimilarity to decompose a set of elements, each described by a number of variables, in two or more subsets mutually disjointed, named clusters. The underlying concept of this aggregation is to maximize the similarity among elements that are included in the same cluster, while maximizing the difference within every couple of elements that belong to different clusters (Kaufman and Rousseeuw, 2009). Differently from other techniques (*e.g.* discriminant function analysis), in cluster analysis the features that define the clusters are not pre-determined: they rather emerge from the clustering itself. This requires to give an ex-post interpretation of the clusters obtained, which often urges scholars to trade-off the number of considered clusters against the homogeneity among the elements within every cluster.

Out of the 28 EIPs instances, we did separate cluster analyses for organizational and sustainability dimensions. We considered all the variables included in the framework and assumed two possible values for each of them, according to the binary scheme depicted in Table 1. The analysis was conducted utilizing a hierarchical agglomerative approach based on the log-likelihood distance. This approach consists in aggregating elements into a number of clusters that progressively diminishes: at every step, the clusters previously obtained are compared among each other and the more similar of them aggregated according to a specific rule defined by the selected clustering method. We adopted the unweighted pair-group average rule as clustering method, namely once a new cluster emerges, the (dis)similarities it has with the other existing clusters are computed based on the average (dis)similarity between all the members in each group. During clustering, recalculation of distances must consider the number of objects previously merged in each cluster, in sharp contrast with single and complete linkage analyses, which are not influenced numerically by cluster size. This method is intermediate between the single and complete linkage strategies, thus attempting to compensate deficiencies of one strategy by the advantages of the other (Sokal and Michener, 1958).

Table 5. The resulting clusters for the organizational dimension.

	Cluster ORG-1	**Cluster ORG-2**	**Cluster ORG-3**
Europe	Artois-Flandres, France Plaine de l'Ain, France Crewe Business Park, UK	Kalundborg, Denmark Uimaharju, Finland Torino Environmental Park, Italy NISP, UK Vreten Park, Sweden	Hartberg Eco Park, Austria Rantasalmi, Finland Arbois Mediterranée, France Value Park, Germany Lopez Soriano, Spain
North America	Innovista, Canada Devens, USA	Burnside, Canada Brownsville, USA Cape Charles, USA	
South America	Santa Cruz, Brazil	La Cantábrica, Argentina Paracambi, Brazil	
Asia		Guitang, China TEDA, China Naroda, India	Nanning Sugar Co, China EBARA Corporation, Japan Kokubo, Japan
Oceania		Kwinana, Australia	

Table 6. The resulting clusters for the sustainability dimension.

	Cluster SUST-1	**Cluster SUST-2**	**Cluster SUST-3**
Europe	Artois-Flandres, France Rantasalmi, Finland Plaine de l'Ain, France Torino Environmental Park, Italy	Uimaharju, Finland Arbois Mediterranée, France Crewe Business Park, UK	Hartberg Eco Park, Austria Kalundborg, Denmark Value Park, Germany NISP, UK Lopez Soriano, Spain Vreten Park, Sweden
North America	Burnside, Canada Innovista, Canada Devens, USA	Brownsville, USA Cape Charles, USA	
South America	Paracambi, Brazil Santa Cruz, Brazil	La Cantábrica, Argentina	
Asia		TEDA, China EBARA Corporation, Japan Naroda, India	Guitang, China Nanning Sugar Co, China Kokubo, Japan
Oceania		Kwinana, Australia	

After the inspection of the dendrogram, we fixed at three the number of clusters. For internal validation, we use a measure that reflects the compactness and separation of the cluster partitions. In particular, to measure the quality of clusters in terms of their cohesion and separation and validate our assumptions, we measured the Silhouette width coefficient (Rousseeuw, 1987). The Silhouette width is the average of each observation's Silhouette value, where the Silhouette value measures the degree of confidence in the

clustering assignment of a particular observation, with well-clustered observations having values near 1 and poorly clustered observations having values near −1. We found a Silhouette width equals to 0.5, which proves the goodness of our cluster results.
Table 5 and 6 summarize the results of the clustering for the organizational and sustainability dimensions, respectively. For each dimension, three clusters have been identified: ORG-1, ORG-2, and ORG-3 for the organizational dimension, and SUST-1, SUST-2, and SUST-3 for the sustainability dimension.
Three organizational models for EIPs emerge from the cluster analysis with respect to the organizational dimension. Specifically, ORG-1 includes 6 EIPs, which are strongly characterized (80 to 100%) by a top-down development process, the existence of an anchor tenant, an heterogeneous productive system, shared support services, and cooperation among firms and with governmental agencies. At the opposite, shared information systems or cooperation with universities and research centres are scarce (less than 20%) in the EIPs included in ORG-1. What make the cluster ORG-1 different from the other two clusters are the regular existence of cooperation with governmental agencies and the rare occurrence of cooperation with universities and research centres. ORG-2 includes 14 EIPs. It is strongly characterized (100%) by a system of cooperative relationships among firms and the lack of anchor tenants. Finally, ORG-3, which encompasses 8 EIPs, is strongly characterized (75 to 100%) by low heterogeneity and low governmental support, a bottom-up development process, and collaborative relationships among the EIP firms, whereas the collaborations with governmental agencies are scarce (13%). Table 7 summarizes the former observations and reports the occurrence of the organizational variables' values in the three organizational clusters: a high (or a low) percentage of a given variable in a cluster shows that the EIPs belong to that cluster hare homogeneous as for the value assumed by that variable. Nonetheless, it is noteworthy that this condition is not enough to infer the relevance of that variable in defining the cluster, as similar percentages may occur in more than a cluster (possibly, in all the clusters). For instance, Table 7 shows that cooperation among companies homogeneously occurs in all the organizational clusters.

Table 7. Occurrence of organizational variables' values in the organizational clusters.

Clusters number of EIPs	**ORG-1** 6	**ORG-2** 14	**ORG-3** 8
[top-down] development process	**100%**	64%	**25%**
Existence of an anchor tenant	**100%**	**0%**	63%
Governmental support	67%	57%	38%
[high] heterogeneity	83%	79%	**0%**
Cooperation among companies	83%	100%	88%
Cooperation with universities and research centres	17%	50%	50%
Cooperation with governmental agencies	**100%**	57%	**13%**
Shared information system	17%	29%	25%
Shared support services	100%	79%	63%

Table 8. Occurrence of sustainability variables' values in the sustainability clusters.

Clusters number of EIPs	**SUST-1** 9	**SUST-2** 10	**SUST-3** 9
By-products exchange	67%	70%	89%
Sustainable use of natural resources	100%	100%	100%
Adoption of best available techniques	78%	70%	67%
Eco-design	**100%**	10%	11%
Green procurement	56%	10%	11%
Sustainable transportation management	67%	**10%**	67%
Landscape protection	**100%**	60%	**11%**
Environmental compliance	89%	40%	67%
Social welfare services	**89%**	30%	33%
Training and education	100%	**10%**	100%
Community awareness and participation	56%	40%	44%
Product responsibility	**67%**	0%	0%

A similar analysis has been conducted to characterize the EIPs along the sustainability dimension (see Table 8 for the occurrence of the sustainability variables' values in the sustainability clusters). As we expected from the definition itself of EIP, we found that the sustainable use of resources is common to all the EIPs. Other practices, such as the adoption of best available techniques and by-products exchange, are extensively adopted by the analysed EIPs. As such, the above variables are barely effective to distinguish EIPs among

each other. Except for these similarities, the results of the cluster analysis show that the adoption of sustainability practices is quite common for the 9 EIPs that belong to SUST-1. In particular, to a large extent, they adopt practices for eco-design, landscape protection, and green procurement. Initiatives for improving social welfare and ensuring product responsibility are also extensively implemented. Clusters SUST-2 and SUST-3 encompass EIPs (10 and 9, respectively) that adopt a narrow set of sustainability practices. For example, initiatives for product responsibility lack in all the EIPs, whereas other sustainability practices, such as those for eco-design, green procurement, landscape protection, social welfare services, and sustainable transportation management systems, are less frequently adopted.
The analysis shows that certain variables (*i.e.* cooperation among companies, shared support services, sustainable use of resources, adoption of best available techniques, by-products exchange) assume the same value for all the considered EIPs, or at least for a large majority of them. Therefore, it emerges that certain organizational features as well as environmental practices seem almost necessary for the existence itself of the EIP. The other variables, namely those associated with organizational features and sustainability practices that less frequently occur, could then be used to differentiate among EIPs.
Finally, without pretending to identify cause-effect relationships, we investigated whether a correspondence exists between the organizational structure of EIPs and the adoption of sustainability practices. To do this, we compared the identified organizational models (associated with clusters ORG-1, ORG-2, and ORG-3) with clusters SUST-1, SUST-2, and SUST-3 associated with the sustainability dimension (Figure 1).

		Organizational dimension		
		Cluster ORG-1	*Cluster ORG-2*	*Cluster ORG-3*
Sustainability dimension	Cluster SUST-1	Artois-Flandres, France Plaine de l'Ain, France Innovista, Canada Devens, US Santa Cruz, Brazil	Torino Environmental Park, Italy Burnside, Canada Paracambi, Brazil	Rantasalmi, Finland
	Cluster SUST-2	Crewe Business Park, UK	Uimaharju, Finland Brownsville, US Cape Charles, US La Cantábrica, Argentina TEDA, China Naroda, India Kwinana, Australia	Arbois Mediterranée, France EBARA Corporation, Japan
	Cluster SUST-3		Kalundborg, Denmark NISP, UK Vreten Park, Sweden Guitang, China	Hartberg Eco Park, Austria Value Park, Germany Lopez Soriano, Spain Nanning Sugar Co, China Kokubo, Japan

Figure 1. Correspondences between ORG-clusters and SUST-clusters.

The comparison shows that the majority of EIPs (83%) belonging to ORG-1 also belong to SUST-1. This suggests that EIPs that developed thanks to top-down initiatives, with a high heterogeneity, and characterized by the presence of collaborative networks among firms and with governmental agencies, anchor tenants, and shared support services, are more likely to adopt a wider range of sustainability practices. On the contrary, only a small percentage of EIPs in ORG-2 and ORG-3 (21% and 13%, respectively) belong to SUST-1. Indeed, the largest quota of EIPs in ORG-2 (50%) belongs to SUST-2, whereas the majority of the EIPs in ORG-3 (63%) belong to SUST-3. The mismatch between ORG-3 and SUST-1 suggests that EIPs that developed through a bottom-up process, with a low heterogeneity, and characterized by a weak support and cooperation with governmental agencies, are less prone to extensively adopt sustainability practices.

7. Conclusions

This paper has investigated Eco-Industrial Parks (EIPs), namely a community of firms located in the same geographic area and linked in a network of collaborative relationships, which leverage on the synergistic effect to reduce the environmental impact and create benefits for the local community, as well as exploit new business opportunities. Even though this topic has been extensively addressed in the literature, to our knowledge there is a lack of studies that aim at identifying possible patterns in terms of both organizational structure and sustainability practices. Our paper fills this gap by proposing a framework that characterizes EIPs along two dimensions of analysis, namely organizational and sustainability dimensions. Every dimension has in turn been decomposed into several variables, and each variable associated with a binary value. We have then applied our framework to 28 EIPs located in diverse geographic areas. A cluster analysis has been carried out based on the value assigned to all variables characterizing any EIP: for each dimension, three clusters have been obtained and described according to the identified features. The analysis shows that certain organizational features as well as environmental practices seem almost necessary for the existence itself of the EIP. The other variables, namely those associated with organizational features and sustainability practices that less frequently occur, could then be used to differentiate among EIPs. This has allowed different models of EIPs to be defined. Furthermore, by comparing the clusters resulting for the organizational dimension with those resulting for the sustainability dimension, we have investigated whether a correspondence exists between the organizational model and the adopted sustainability practices. Results suggest that EIPs promoted or supported by governmental initiatives, with a high heterogeneity, and characterized by the presence of collaborative networks among firms and with governmental agencies, anchor tenants, and shared support services, are more likely to adopt a wider range of sustainability practices. Differently, sustainability practices are less adopted in EIPs developed through a bottom-up process, with a low heterogeneity, and characterized by a weak governmental support and scarce collaboration with governmental agencies.

In other words, based on the empirical evidence, EIPs promoted or supported by governmental initiatives more extensively apply sustainability practices than EIPs that emerge as spontaneous initiatives with limited public support. Similarly, heterogeneity of actors within an EIP is associated with the adoption of a higher number of sustainability practices.

Our study provides an original contribution to the existing literature. In particular, we have developed a framework that allows EIP to be characterized along two dimensions, each of them accurately described through a broad set of variables. Furthermore, thanks to an extensive analysis on 28 cases and the adoption of cluster analysis, we have identified patterns in terms of both organizational structure and sustainability practices.

Even though the results do not reveal cause-effect relationships, it seems reasonable that the organizational aspects (*e.g.* those related with the EIP formation) might impact on the adoption of sustainability practices. Under this perspective, our results suggest some policy implications to enhance an EIP's sustainability. First, governmental agencies should support EIPs, for example through educational programmes as well as suitable infrastructures, and norms that incentivize companies in sustainably managing by-products and waste streams. Second, collaborative relationships should be strengthened, both among firms and with governmental agencies. The former, in fact, enable industrial symbiosis, the latter may favour the spread of best practices among different EIPs and ease the access to subsidies and their efficacy. Third, strategies should be pursued to favour a top-down development process, namely a process driven by an initiator. In this sense, it is key the role of government agencies, associations of companies, trade unions, and chambers of commerce. Finally, the heterogeneity among the EIP's actors should be fostered, as it may facilitate the establishment of symbiotic transactions and is in general associated with a higher resilience. For example, local governments should formulate policies that attract firms located outside the EIP as well as stimulate the creation of new firms, especially if operating in sectors not yet represented in the EIP.

As exploratory, our study presents some limitations. We considered a number of EIPs, which is relatively limited, although the set is selected so as to be quite representative of diverse geographic areas. Furthermore, we used secondary data, retrieved by desk analysis, so involving possible inaccuracy, mainly due to the fact that data refer to different time periods or come from studies characterized by different aim, scope, and depth.

Further research could address the above limitations. By increasing the number of analysed EIPs, new dimensions and more variables could be considered while preserving the statistical reliability of the analysis: selected performance indicators or exogenous variables could be investigated. The former would shed light on possible antecedents of an EIP's success, should a correlation emerge between the organizational and sustainability dimensions, on the one hand, and the performance indicators, on the other hand. Exogenous variables, such as the geographical location, would allow the influence of culture and policy framework to be taken into account.

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