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Review

Can we replicate eco-industrial parks? Recommendations based on a process model of EIP evolution

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ABSTRACT

This article develops a process model of eco-industrial park evolution. It draws on two article communities previously identified through a scoping literature review, concerning the development of eco-industrial parks and industrial symbiosis, respectively. The study seeks to find answers to the main research question: How should phases of eco-industrial park evolution and their critical factors be considered when replicating or reproducing existing eco-industrial park successes in new contexts? By identifying four phases of eco-industrial park evolution and shedding light on the critical factors influencing these, the study presents replication and reproduction recommendations, and thereby provides knowledge to diffuse success stories into other contexts. The study undersores the need for a flexible and adaptive approach to diffusion of EIP successes, considering elements such as the costs and benefits of replication, the idiosyncratic nature of some critical factors, and their relevance in the new context. Moreover, the results of the study highlight the need for capacity building in the replicatee context, focusing on mobilizing and activating existing resources to curate initiatives for EIP formation. Strong collaboration between the replicator and replicatee, where empowerment is central, is seen as a key factor in effective EIP replication.

1. Introduction

As the global economy is facing a need to economize on resources and mitigate emissions from human activities, not only international solutions are suggested for this global problem, but collective approaches at the local level are receiving attention as well. Industrial solutions, in which two or more organizations exchange, share, or transact excess resources, such as by-products or waste, in a systematic way to reduce the consumption of virgin material, energy inputs, and the generation of waste and emissions has received increased attention in research (Mallawaarachchi et al., 2020; Vahidzadeh et al., 2021). This collaborative concept has its roots in the industrial ecology described by Graedel T.E. and Allenby (1993) and Ayres and Ayres (2002), and discussed further by Ehrenfeld (2004) describing industrial symbiosis (IS) concept, which eco-industrial parks (EIPs) build upon (Behera et al., 2012). EIPs are thus a way to demonstrate industrial ecology in practice (Roberts, 2004).

This article concerns the evolution of EIPs. Taddeo et al. (2012) refer to an EIP as the companies' geographical agglomeration model, irrespective of whether we are analyzing industrial districts, business networks, local production systems, flexible specialization, or regional clusters. These operate with the focus on optimal circulation of materials where waste resources from one company being the resources for another and mimicking natural ecosystems, taking the relation between environment, business and urban landscapes into consideration creating a valuable inter-organizational network with multiple benefits (Tudor et al., 2007). Gibbs and Deutz (2005) state that especially this inter-organizational networking and exchanges of waste or energy must be in place to earn the definition of an EIP. Also, Côté and Cohen-Rosenthal (1998) see eco-industrial parks mainly as systems of firms that are interacting and interdependent. A number of definitions of EIPs are presented, where interactions among businesses and their environment (ibid.) are the essential feature across these definitions. These apply the principles of industrial ecology (Interacting ecosystems, cycling of materials and energy, networking and cluster building, and sustainable development) in a specific location (Gibbs and Deutz, 2007). Industrial ecology research has provided knowledge on what drives the coming about and evolution of such industrial clusters. This, can be used

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in practice to revitalize existing clusters (Taddeo et al., 2012) and/or to replicate these by designing and creating new, more sustainable industrial areas.

Some typologies, such as the one by Scafà et al. (2020), distinguish between the way in which these EIPs come about, whether there was a bottom-up approach, where relationships develop independently from a facilitator and through shared agreements between businesses, or programmed EIPs that are planned and implemented through a top-down approach (ibid.). Both approaches have some drawbacks, such as e.g. top-down EIP planning encountering challenges due to e.g. lacking engagement of firms (Chertow, 2000), while bottom-up approaches to EIP development can show a limited employment of sustainability practices (Bellantuono et al., 2017) among other factors. Bottom-up approaches require e.g. existing co-location of firms, a regional culture, or similar production processes that foster relatability (Dai et al., 2022). Costa and Ferrão (2010) provide an alternative to this dichotomy and propose the middle-out approach to EIP development, a facilitated approach. This approach has received increasing attention and support among researchers and practitioners (Tudor et al., 2007; Behera et al., 2012), as in many practical cases of EIP development, actors neither self-organize nor follow blindly a top-down designed development plan, but instead work with local conditions while getting inspiration from outside. This study therefore builds on the middle-out approach by emphasizing the strategic aspect of the action taken (including the vision and initiatives to support it) for both its development and replication to other contexts.

Over time, research has presented a myriad of process models that aim at describing how exactly EIPs come about and develop over time, and which phases this development follows.

However, the literature seems to lack a synthetized process model for EIP development with specific critical factors driving (or inhibiting) each phase, which can assist in the development of new EIPs in same or new contexts, hence replicating the existing ones. In order to be able to replicate the best practices of EIPs, and thus contribute to new EIPs coming about, there is a need to better understand EIP evolution and the critical factors driving it.

Gibbs and Deutz (2005) state that a variety of strategies can be used to make EIPs come about and develop over time. The authors emphasize the design of EIPs as a strategy for EIPs coming about and mention the characteristics that must be in place. First, a long-term vision must be agreed between the relevant actors. Then, the emphasis must be on networking, collaboration and community developing, as this is the factor that will drive resource exchanges in the long term and create an eco-industrial network among the firms that is different than other greening initiatives.

One factor that has received less attention is that the coming about and development of EIPs does not happen in a vacuum and that successful examples, such as Kalundborg in Denmark, have inspired new eco-industrial park developments worldwide. EIP coordinators from various contexts are increasingly collaborating with each other internationally, transferring know-how from one, successful EIP to another, with a focus on replicating the good examples from one context to the other context. Another example is Icelandic Ocean Cluster, which goes as far as to spread and "copy" their concept to other contexts, leading to the emergence of the New England Ocean Cluster and Pacific Northwest Ocean Cluster, among others (Iceland Ocean Cluster, n.d.). We refer to this dynamic of diffusing successful solutions as mechanisms of reproduction and replication, which describe different extents of a "diffusion of innovations" (Winter and Szulanski, 2001, p. 731) from one context to another. We want to highlight and start addressing this gap in literature by discussing the relevance of critical factors in the EIP development process when replicating successes to other contexts.

The present study therefore revolves around the following research question: *How should phases of EIP evolution and their critical factors be considered when replicating or reproducing existing EIP successes to new contexts?*

To answer the research question, we first answer the guiding question of *what are the phases of EIP evolution, and which critical factors drive these?* The aim is to identify critical factors influencing EIP evolution and outline the resulting process model. This allows us to nuance the generalizability of these factors by discussing in how far they are replicable or reproducible to other contexts and for new EIPs, and by this start a discussion on the reproduction and replication dynamic of EIP development.

First, we present the state of the art regarding the development and (lacking) literature on replication and reproduction of EIPs (section 2). After laying out our methodology (section 3), we present the results and answers to the guiding question (section 4). Finally, we discuss the implications of the results for replication and reproduction of EIPs and connect them to the research field and practice (section 5), concluding with recommendations for avenues for future research (section 6).

2. State of the art and analytical framework

2.1. EIP evolution

Previous research has tried to make sense of the EIP literature in different ways. Tudor et al. (2007) critically examined the use of EIPs as a means of improving resource efficiency within companies and reviewed literature to understand the key environmental, economic, social, and institutional driving and restraining factors that influence the successful development and functioning of an EIP. They mention several challenges for EIP development pointing at the fact that EIPs are fragile systems that can be disrupted by problems with information dissemination, communication, price changes that makes exchange of resources less attractive, and a series of problems that have to do with coordination of the ecosystem. Tellier et al. (2019) conducted an analysis of the multidisciplinary literature positioning the concepts surrounding the sustainability of business parks. Dai et al. (2022) conducted a systematic literature review of 61 articles that address transformation of ageing industrial parks to EIPs. In their introduction they differentiate between two main literature streams: One that addresses EIPs from a firm- or value-chain perspective and emphasizes trust, information exchange, and local processes for the emergence of IS, and another that adopts a macro perspective and emphasizes policies and incentives and evaluates national EIPs programs. In their systematic literature review, they identify a five-stage process of EIP transformation and influencing factors, among which accentuating the role of five key stakeholders. They highlight how stakeholders work together over time for EIP transformation.

Other reviews of literature focused on specific aspects of EIP development. Butturi et al. (2019), for example, provide an overview of the scientific literature on energy synergies within eco-industrial parks, which facilitate the uptake of renewable energy sources at the industrial level, potentially creating urban-industrial energy symbiosis. They categorize urban-industrial energy symbiosis solutions, in terms of design and optimization models, technologies used and organizational strategies. Other reviews target even more detailed aspects of EIP development, such as driving and limiting factors for EIPs (Sakr et al., 2011), indicators to manage EIPs (Felicio et al., 2016), quantitative tools for facilitating IS in industrial parks (Kastner et al., 2015), or the roles of geospatial technology for selecting sites for EIPs (Nuhu et al., 2021).

However, no literature review has yet been conducted from a process (design) perspective that captures a variety of approaches for EIP development.

2.2. EIP reproduction and replication

While several scholars certainly highlight the context-dependency of EIP development, to our knowledge none have discussed how this influences the replication of successful EIPs experiences and solutions. In none of the above-mentioned review articles have scholars connected

EIP development phases to the ongoing diffusion of successful EIP developments taking place in practice from one context to another.

The various cases described in the literature show, however, that the diffusion from one existing context to new contexts can take place in a later development phase of the original EIP, where successes and/or potential failures have been acknowledged, and ideas and lessons learned worth being spread to other contexts are identified. We use diffusion as an overarching meta-concept differentiating between *reproduction* and *replication* dynamics and conceptualize these as two mechanisms of diffusing successful EIP solutions from one context to another one. Diffusion is thus in itself not a phenomenon, but a new dynamic of EIP evolution, where the EIP in context A (EIP replicator) develops by replicating or reproducing its best practices into Context B (EIP replicatee). By this, the EIP replicatee (in context B) comes about and develops into a new EIP, with the inspiration, knowledge and experience injection from the EIP replicator (Context A). Fig. 1 visualizes this regarding an EIP's development.

The mechanisms of replication and reproduction are understood and defined in this study as the diffusion of local EIP solutions (from context A) to other contexts (context B), based on the knowledge and learning accumulated from and about the initial contexts.

To arrive at a conceptualization of the two mechanisms and differentiate between them, we rely on dictionary definitions, strategic management (Jonsson and Foss, 2011), and organizational and management literature (Winter and Szulanski, 2001), supported by the existing literature on EIP and IS (see Table 1 below).

Table 1
Two mechanisms of diffusing existing EIPs success.

	Reproduction	Replication
Dictionary definition	"The act or process of producing new life" (Cambridge Dictionary, 2023b), "a copy of something, especially a painting, or the process of copying something" (Cambridge Dictionary, 2023b)	"The act of making or doing something again in exactly the same way, or something that is made or done in this way" (Cambridge Dictionary, 2023a), "the process by which organisms and genetic or other structures make exact copies of themselves" (Cambridge Dictionary, 2023a)
Org. & management theory	A flexible approach, permitting to develop alternatives that fit various contexts and environments (Jonsson and Foss, 2011)	'McDonalds approach' (Winter and Szulanski, 2001, p. 730)
Own definition	Emergence of a new EIP through flexible and adapted diffusion from an existing EIP	Copying the EIP in its entirety or in modules; a 1:1 copy

2.2.1. Replication

Management theory describes *replication* as an organizational form, which contributes to the creation of new entities similar to an existing one and delivering a similar specific product or service. The literature calls these 'outlets' (Winter and Szulanski, 2001, p. 730). We conceptualize the equivalent of outlets, as visualized in Fig. 1, as EIP replicatee from context B. The original entities (EIP replicator), serve then as *"the historical template"* (ibid.) for the new outlets. Furthermore, sometimes the management literature refers to this type of strategy of replication as the "McDonalds approach" (ibid.), stating that generally there is an initial entity or process regarded as a successful one and presenting a guiding example for a new one, the outlet, which comes about from copying the original example. By this, new outlets, similar to the original one, can come about in various contexts. In such processes of replication, efforts usually focus on reproducing the success from the original site. We lean on this conceptualization to define replication in the context of EIP development, i.e. diffusing the knowledge and experiences, lessons learned – the historical template – to another context, and by that contributing to the coming about and development of a new EIP.

In the context of EIP development, replication can be challenging, because it requires a nexus of various factors among which inspiration, site visits, and platforms of experience exchange play an important role (Mortensen and Kørnøv, 2019). Thus, it necessities a process of knowledge diffusion. For instance, Schlüter et al. (2020) determine that existing industrial symbioses influence the emergence of new ones and contribute to industrial symbiosis network (ISN) development. Many of the mechanisms they identify transcend the boundaries of single IS linkages and span across several IS networks. They observe for example, that in several cases targeted as well as non-targeted, knowledge diffusion played a role in the emergence of new symbioses. The example of the fly-ash-symbiosis (where a by-product of coal combustion is used as a supplementary cementitious material in concrete) illustrates how the knowledge exchanges following earlier symbioses of this kind have contributed to its emergence, without targeting it from the begging. This type of symbiosis could be replicated as it did not need major adaptations to a local context. This is, however, rarely the case in EIP development.

The subject of replication needs to be elaborated on. Tsvetkova et al. (2015) addresses the replication of ecosystems, in the contexts of a biogas-for-traffic-solution. The authors specify that replication concerns the transfer of accumulated business knowledge from one context to another. Furthermore, the authors mention that the replication is a suitable approach for businesses for sustainable development towards distributed structures and interconnected systems. They also argue that more value can be created if the ecosystem that is replicated is viewed as a modular system with various interconnected parts in a meta-ecosystem. This is also in line with Korhonen (2004) that argues that industrial system is a subsystem to the parent ecosystem, and it is turn consists of multiple subsystems. The subsystems or modules can e.g. be organized according to the specific symbiotic flows, and/or the aspects or critical factors important for EIP development (e.g., infrastructure, technology). Replication in this case is flexible, and takes place at the modules' level, each of these being replicated from one context to another by various means, and leading to the diffusion of the EIP replicator's learnings to the EIP replicatee.

2.2.2. Reproduction

While replication is characterized by knowledge diffusion leading to an almost identical copy of existing solutions, *reproduction* is characterized by a process adaptation to local contexts (see Table 1). In consequence, reproduction puts less emphasis on copying successful examples, but instead focuses on learning from existing EIP

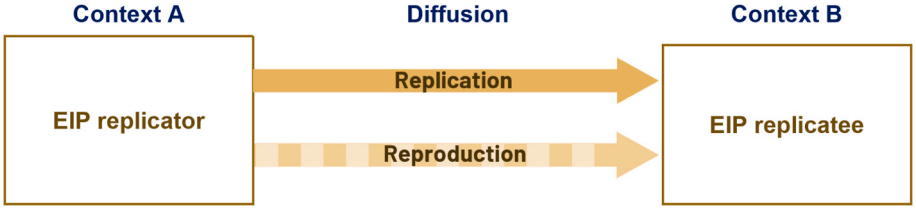

Fig. 1. EIP evolution process including the two diffusion mechanisms: Reproduction and replication.

development and adapting these learnings to new contexts. Jonsson and Foss (2011) argue for this flexible approach, which permits developing alternatives that fit various contexts and environments, focusing on adjustments in order to adapt to local environments, and under the impact of new learning.

In the literature on EIP development, examples of factors that drive reproduction from one context to another one occur. For instance, Schlüter et al. (2020) summarize that literature indicates that strong capacities, embeddedness, and technological infrastructure are factors that support further IS emergence and that can represent a link between existing and new symbioses that are different from a direct copying of solutions. In terms of capacities, they state that specific capacities accumulate through development of symbiotic relationships, and these can in turn influence the emergence of new linkages. Mortensen and Kørnøv (2019) find that individual, organizational, and institutional capacity is built when IS emerges, and at the same time this build the ground for new symbioses. Tsvetkova et al. (2015) also stress that while some of the parts of the symbiotic system can be transferred from one context to another, through copying them, others need adaptation through continuous learning and experience exchange.

Using this conceptualization, we distill the learnings from the process model of EIP evolution to shed light and discuss implications for EIP replication and reproduction for new EIP coming about.

3. Methodology

The study starts in a systematic literature review. Even though a case study could have been applied, it is difficult *"to examine the growth patterns of IS networks empirically"* (Zhu and Ruth, 2014, p. 38) and *"complete timeline data of IS networks are not readily available, making regression analysis of a step-by-step network growth not feasible"* (ibid.). Additionally, empirical research describing EIP cases in various contexts is rich. Learning from these through a systematic literature review was found appropriate.

To develop a process model for evolution of EIPs, the methodology took inspiration in the steps suggested by Jabareen (2009) and followed the procedure displayed in Fig. 2.

The steps taken to conduct this systematic review of literature are presented below.

1. Choosing data sources

The first activity concerned the mapping of selected data sources, described as phase 1 by Jabareen (2009). For conducting a systematic review of literature, scoping reviews can represent a valuable point of departure, as they provide insights into complex or heterogeneous bodies of literature (Pham et al., 2014). This is what the present study did by basing its research question on a previously conducted scoping review of the scientific literature on sustainability in industrial areas (Schlüter & Bekamiri, forthcoming). Here, distinct communities of research have been identified and particularly two of these were of interest to us, as they refer to the design and development of EIPs and ISNs. These composed a total of 123 articles, of which 69 articles refer to IS development and 54 articles to EIP development. As these concepts are closely related, these two communities were the point of departure for the following analysis.

2. Shortlisting and analysis of selected articles

Phase 2 concerns an extensive reading and categorizing of the selected data (Jabareen, 2009). In our case, we viewed titles and abstract of each of the 123 articles and inductively allocated topics to them, which we then merged into larger categories. For the first community on IS, these categories were: Context for IS development; Goal-directed IS management; IS opportunity identification; Tools supporting the process of IS creation; IS benefits, drivers, and barriers; IS

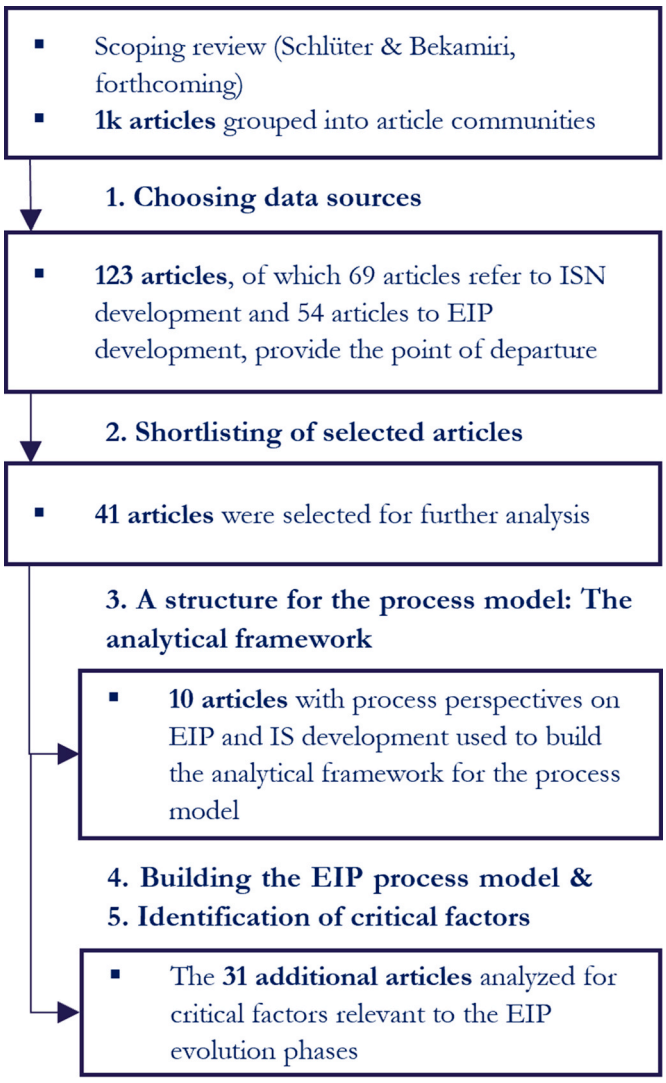

Fig. 2. Selection of articles and steps taken in the methodology.

from supply chain perspective; Robustness/resilience; IS facilitation approach; Governance types; Profit & cost allocation; public–private interplay for IS; IS implementation; IS environmental performance; Economic value from IS; IS decisions and design; IS & Industry 4.0. For the second community on EIP, a similar categorization has been conducted. We used this information on the articles to allocate them into topical groups. Then, the topical groups were either selected for further reading or set aside.

To select articles for further reading, they needed to provide information about EIP evolution (especially phases, roles of actors, barriers & drivers, governance/curation, and organizing were judged as interesting for finding critical factors for phases of EIP development); they reflect on elements important in different phases or highlight who is driving which parts of the process. Tools on how to determine optimal design characteristics or insights reached for specific cases alone were not enough to qualify for reading, it needed to provide more information, for example how actors decide and work with these designs, how the designs developed over time (development paths), or how contextual factors influenced the development.

As a result of this process, 41 articles were selected for further analysis. The list of selected articles and their use for different purposes is summarized in Appendix A. The articles build on a total of 98 cases of real-life EIPs, of which 45 are located in Europe, 40 in North America, 6 in Asia, 5 in Central and South America, and 2 in Oceania. Some studies

rely on a large number of cases, either by using selected characteristics of the cases (Côté and Cohen-Rosenthal, 1998) or by conducting large surveys (Tessitore et al., 2015). This partly contributes to the high number of cases from USA and Italy. Other studies conduct in-depth studies of one or two cases, which seems to be characteristic for studies of Finnish IS networks (Pakarinen et al., 2010; Patala et al., 2020; Uusikartano et al., 2022). Longitudinal studies of EIP evolution are rare. Much more often, the EIP cases were analyzed at different points of development. 13 cases are described as planned, pre-operational, or as a potential EIP, while the remainder had at least one resource exchanges in place. However, some represent much less developed networks than others (e.g. the evolving network of interfirm exchanges in Guayama, Puerto Rico, that Mileva-Boshkoska et al. (2018) analyze compared to the much older and more developed Kiwana EIP in Australia (Faria et al., 2021)). We know from previous research that, in practice, the majority of EIPs are in early stages of development (Gibbs and Deutz, 2007) and several examples of these are also found in our literature sample (e.g. Moerdijk EIP project analyzed by Heeres et al. (2004)). Due to the lack of longitudinal studies on the majority of cases and the varying depth with which the studies investigate the cases, a comparative process analysis between EIP evolutions and their critical factors is not possible. But the number of real-life cases used underlines the validity of the critical factors observed at different points of EIP evolution.

3. Providing a structure for the process model: setting up the analytical framework

As one topical group concerned "Process perspectives" on EIP and IS development, we took departure in the 10 articles belonging to this group to build an analytical framework for the process model (see Appendix B for an overview of existing process models). The results of this step were four distinct process phases and definitions of each phase. This analytical framework provided the lens to look at the remaining articles.

4. Building the EIP process model

These 10 articles, together with the remaining 31 articles, were distributed among the four authors for detailed reading. The authors read the articles, extracted relevant information, and wrote a summary for each article. To increase the validity and credibility of the findings, investigator triangulation was used, and two researchers were included

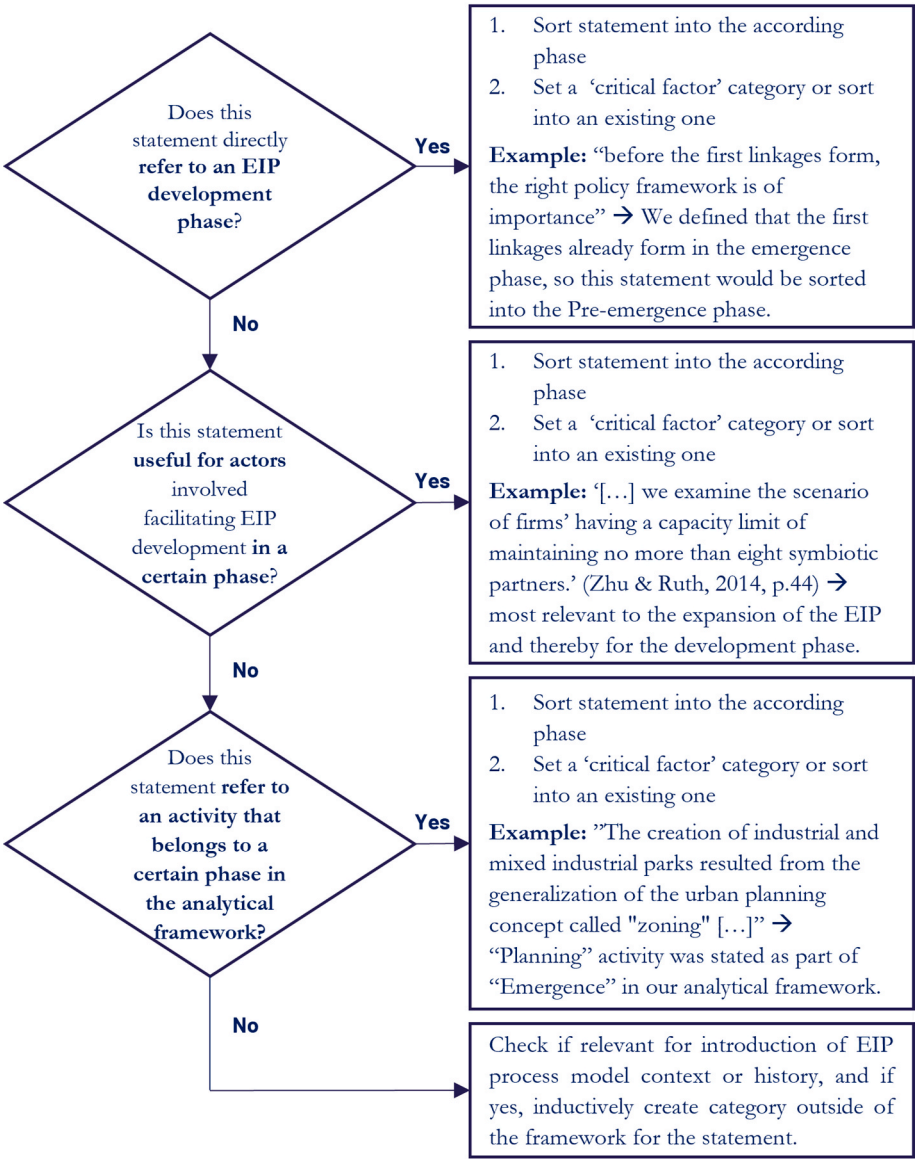

Fig. 3. Flowchart for allocating statements from article summaries to phases of EIP evolution of the analytical framework.

in the analysis of each article. Furthermore, regular meetings were held to agree on relevant aspects of interest for the process model. The summaries' content was then (i) sorted according to the previously developed analytical framework (phases) and (ii) sorted into other categories, as in some cases, no allocation into phases was possible, and/or the article summary showed additional information that was relevant to the study. The latter content was used to introduce and frame this study. The summaries' content was analyzed using the decision process outlined in the following flowchart (see Fig. 3).

5. Identification of critical factors

As the flowchart indicates, within the phases, statements were inductively grouped into categories to arrive at the critical factors that are of importance in each phase. This process was similar to Jabareen's phase of integrating concepts, as here *"the aim […] is to integrate and group together concepts that have similarities to one new concept. This phase reduces the number of concepts drastically and allows us to manipulate to a reasonable number of concepts"* (2009, p. 54). By revisiting and resorting the content, a synthesis and resynthesis was reached.

6. Discussion in the light of replication and reproduction

It is not possible to formulate a simple theory that is both general and accurate (Weick, 1979). More so, generalization is a common way of theorizing in organizational research (Jackson et al., 2019), which means moving away from context (Tsang, 2013). Our search for phases of EIP evolution and their critical factors entailed a degree of decontextualization, which holds the danger that boundary conditions of the theory remain unexplored and that it becomes less useful in addressing practical challenges (Jackson et al., 2019). This issue is currently faced by EIP practitioners when considering how to apply learnings from EIP literature to their specific circumstances. While several general reflections on EIP evolution have been developed, they often lack an explanation of how far these learnings are applicable to different contexts. Consequently, in the last step of our analysis, we discuss the implications of the identified phases of EIP evolution for EIP coordinators.

4. Evolution of eco-industrial parks

4.1. Phases of EIP evolution

The literature review identified that it is common to describe the development of EIPs through different evolutionary phases. Fig. 4 shows seven representative and influential papers on the subject.

The papers represent a type of process model, in which the framing of the process does not *"include […] everything and where elements are [less] intertwined, enmeshed and joined together"* (Cloutier and Langley, 2020 p. 19). This means that the frame offered is not a very complex and rich theory but that these are useful models due to their parsimony and elegance, which can be represented through *"traditional conceptual tools such as boxes and arrows"* (ibid.). Furthermore, research applying the models acknowledges the complexity and nonlinearity of EIP evolution, e.g., as seen in Chertow and Ehrenfeld (2012, p. 19), who state that *"the boundaries between stages may be fuzzy in practice"* and that *"the stages are discontinuous, the progress across them is nonlinear and cannot be predicted"*. Processes appear as iterative, often represented by loops as in Mortensen and Kørnøv (2019) and Belaud et al. (2019).

Furthermore, some research either focuses on the high level of abstraction and distinguish between various phases of industrial sustainable development or focus on identifying the development phases of a single, specific case. For example, Korhonen (2004) presents a five-level model for regional sustainable development through EIP development that applies industrial ecology principles. At the first level, Korhonen (2004) proposes to distinguish between economic, social, and the ecological subsystems and to pay attention to the physical principles in the construction of the entire EIP system. At the second level, there is the emergence of linkages among the actors in an industrial system which will follow nature's model. Learning form nature can inspire more linkages, and hence more development, which characterize level three. At this point the locality, diversity, and cooperation seem to be important drivers. The fourth level is achieved when a number of considerable linkages connect the actors in the industrial ecosystem into a web of relations that utilize waste materials and energy. The development can then be measured and monitored using various tools, metrics, and instruments to also assess the economic, social and ecological performance of the industrial system at the fifth level. Behera et al. (2012) on the other hand is focusing on the specific case of the development of Ulsan

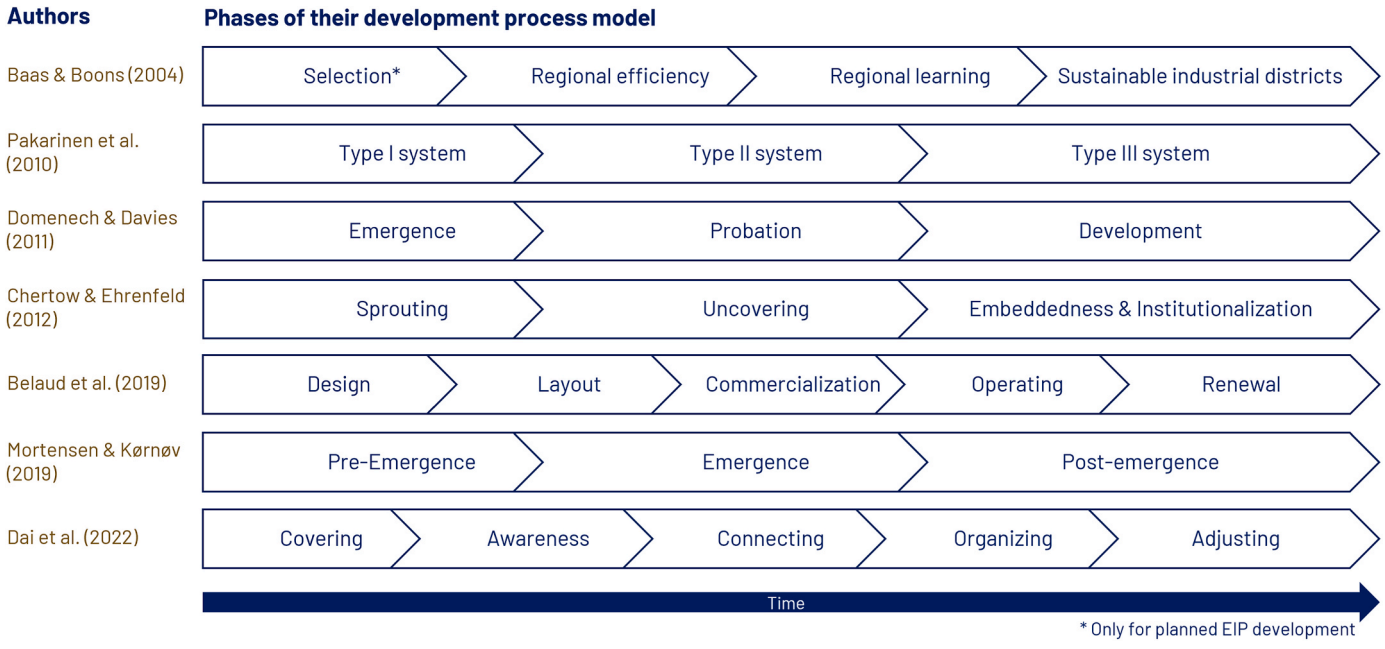

Fig. 4. Phases of EIP evolution according to literature. See Appendix Bfor more detailed analysis.

EIP in Korea, distinguishing between three phases: one characterized by pilot studies to understand the material flows, second where the conceptual ideas were provided and the knowledge was disseminated, and third when a performance analysis was conducted, successes and failures where examined and strategy was revised.

Most of the models focus on actions taken to develop EIP, generally in terms of social interactions that lead to expansion of the symbiosis, increase in the diversity of actors, and cause new connections to be formed as the EIP evolves, as described by e.g., Pakarinen et al. (2010). However, the models show some differences in terms of the kind of development process to which they refer. While planned processes are described in terms such as "Selection" (Baas and Boons, 2004) or "Design" and "Layout" (Belaud et al., 2019), other models emphasize characteristics of self-emerging systems described in terms such as "Sprouting" (Chertow and Ehrenfeld, 2012) and "Regional efficiency" (Baas and Boons, 2004). Costa and Ferrão (2010) transcend this dichotomy and argue for a middle-out approach where planned and designed processes are combined with bottom-up self-organized initiatives.

In this study, we map the characteristics of EIP development across these approaches, as focus is on facilitated EIPs, irrespective of who is facilitating. In effect, the study represents a synthesis of current EIP approaches. We distinguish between four phases of EIP evolution, each having its own characteristics and dynamics. As presented in Fig. 5, these phases are pre-emergence, emergence, probation, and development.

4.2. Process model for EIP evolution

Each phase has outcomes, some of which represent required conditions for entering the next phase. These are often referred to as drivers and enablers that appear as critical factors or contextual conditions (Faria et al., 2021; Gibbs and Deutz, 2005). In the following, we define each phase and present critical factors identified in the literature. Fig. 6 visualizes the phases and their main critical factors.

4.2.1. Phase 1: pre-emergence and its critical factors

The pre-emergence phase is the initial phase before any symbiotic relations emerge, where fruitful conditions are present or are built through various interactions among a multitude of private and public actors to foster EIP evolution. The dynamics may vary from case to case, depending on various factors such as the historical, cultural, and geographical location of the EIP.

At this point in time, the industrial system is undeveloped characterized by linear processes and the absence of symbiotic relations. This is what Pakarinen et al. (2010) refer to as a "Type 1 system." However, *"initial conditions and antecedents"* (Mortensen and Kørnøv, 2019, p. 62) that can foster symbiotic relations (Costa and Ferrão, 2010) exist, which encourage firms to self-organize, often created as outcomes of cooperation between various actors. Mortensen and Kørnøv (2019) identify economic, environmental, technical, cultural, financial, political, historical, and infrastructural factors, geographical proximity, and the existing pool of knowledge as important antecedents. Domenech and Davies (2009) point to interactions between actors within regulatory frameworks, to some extent focused on innovative approaches to waste-flow exchanges, and Costa and Ferrão (2010) argue that the regulatory framework may even occur through the interaction alongside cooperation on economic and environmental landscape, emission permits, and infrastructure development. During this process, symbiotic relations emerge, which include a "selection" of core actors of the future EIP (Baas and Boons, 2004, p. 1077).

At this stage of EIP evolution, our literature review indicates that seven factors are critical. First, the *economic environment* must stimulate EIP emergence. Here, public sector interventions and access to finance are crucial (Mileva-Boshkoska et al., 2018; Gibbs and Deutz, 2005), and there is a need for dedicated economic and environmental institutions (Noori et al., 2020). Second, *geographical location* matters because co-location is a driver for symbiotic relations (Gibbs and Deutz, 2005; Taddeo et al., 2012, 2017), especially if the geographical location is characterized by favorable conditions for *economic and political resources* (Morales and Diemer, 2019, p. 5). Third, the *pool of resources* is a driver for symbiotic relations, either because waste resources that can become valuable input elsewhere are available, or because resources are scarce and thus create an impetus for cooperation between firms and across value chains. For instance, Faria et al. (2021) show how scarcity of fresh water stimulates cooperation across firms. Fourth, *spatial planning* is essential, because the emergence of EIPs often requires that space is reorganized, especially in cases where there are competing demands on space for different types of use, or where space needs to be dedicated to the co-location of firms or as a framework for a specific pool of resources. Here, encouraging public participation is important for easing the coordination between various stakeholders (Behera et al., 2012). Verguts et al. (2016) provide a convincing example of how the interventions and spatial planning of the Flemish government stimulated the emergence of the Koekhoven greenhouse park. Furthermore, Roberts (2004) provides a planning agenda for EIPs, comprising the holistic system approach integrating planning, research, and implementation, creation of strategies, examination of material and energy flows to re-design industrial activities and make them circular.

All of this is, however, non-essential if firms do not come together and populate the space available for EIPs. So, fifth, for the individual actor, the potential of engaging in symbiotic relations is sensitive to the *presence of other firms*. Symbiotic relations often start with bilateral cooperation that eventually leads to agreements and mutual understandings (Faria et al., 2021; Taddeo et al., 2017). The presence of large firms is in some cases important, because large firms possess the resources for driving the process of EIP evolution, capitalize on public investments, and provide a stable economic environment for the sharing of resources, infrastructure, and facilities, thus becoming *"economic anchors"* of the industrial park (Costa and Ferrão, 2010, p. 991). Of course, while the presence of other relevant firms is often guaranteed in cases where EIP emerges through transformation of an existing industrial park, i.e., as a brownfield development, this is not the case when EIPs emerge from a bare field, i.e., as a greenfield development. The potentials for symbiotic relations differ between brownfield and greenfield approaches (Lambert and Boons, 2002), and greenfield development is not always the obvious choice (Conticelli and Tondelli, 2014). However, greenfield development may entail promising opportunities,

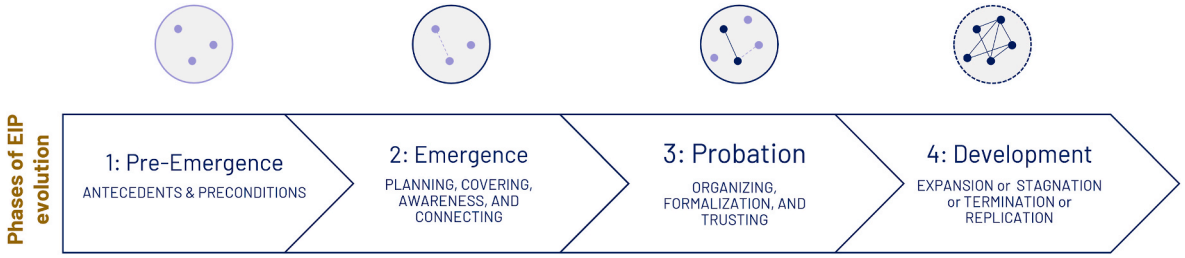

Fig. 5. Analytical framework showing EIP evolution based on current literature.

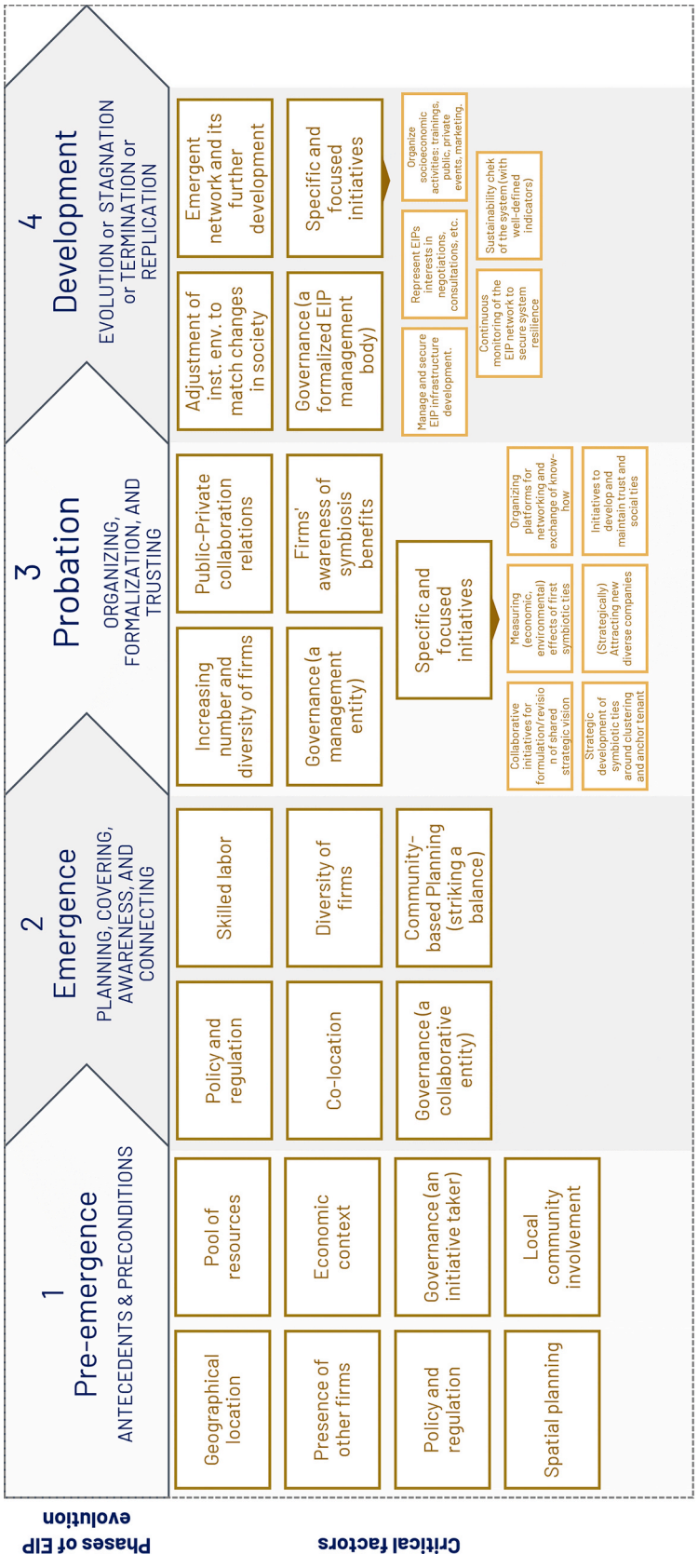

Fig. 6. Process model for EIP evolution: Phases and critical factors.

because when a critical mass of firms exists, facilitated and *"self-organized symbiotic processes"* (Conticelli and Tondelli, 2014, p. 338) among firms can be born and progressively developed. Regardless of the brown- or greenfield developments the businesses must be involved from the beginning, and the process of involving and coordinating partners and stakeholders must be business-oriented (Behera et al., 2012).

The *local community involvement* (sixth factor) may be important to avoid public resistance caused by 'not-in-my-backyard' effects. Emergence of EIPs, both in the case of brownfield and greenfield development, is hampered if lack of involvement causes resistance from influential local political or activist forces (Taddeo et al., 2017; Costa and Ferrão, 2010).

The last critical factor identified relates as well to the working of the social fabric. The *policy and regulation* may stimulate or hamper EIP development. The best way forward is to create an integrated set of policy instruments that can serve as enablers (Costa et al., 2010; Gibbs and Deutz, 2005; Sakr et al., 2011), and which are *"consistent with policies for sustainable industrial development and integrated at national, regional, and local levels"* (Faria et al., 2021, p. 19f). Policy schemes may be decentralized, as in the case of Denmark and Switzerland, or centralized as in UK and Portugal (Costa et al., 2010), but whatever the case, policy schemes need to reflect market conditions in order not to become ineffective (Wang et al., 2022).

4.2.2. Phase 2: emergence and its critical factors

The emergence phase is the phase where initial flow connections come about through various interactions among actors that become aware of the synergetic benefits, reach out to each other, and sit together to explore possible connections. It is the phase where the first knowledge and learning from own processes are created, establishing a growing shared culture.

The emergence phase is characterized by sprouting of resource flows connecting firms. This can occur as the outcome of firms reaching out for each other to achieve resource optimization and efficiency (Baas and Boons, 2004; Chertow and Ehrenfeld, 2012), or it can be stimulated by an outside actor that engages in supporting, selecting, and/or uncovering symbiotic relations (Pakarinen et al., 2010). Pakarinen et al. (2010) describe this state of affairs as a "type 2 system", and it is similar to the "commercialization phase" described by Belaud et al. (2019), "sprouting" as presented by Chertow and Ehrenfeld (2012), the "emergence phase" as coined by Mortensen and Kørnøv (2019) and Doménech and Davies (2011), and the "covering" phase that Dai et al. (2022) use to denominate the transformation of existing industrial areas into EIPs.

The central dynamic of the emergence phase is the development of ties linking firms (Doménech and Davies, 2011). Ties develop as potentials for symbiotic relations are discovered and realized through interactions among actors. These may start as simple and straightforward opportunities for cooperation that lead to the discovery of more opportunities, often resulting in cooperation that gradually increases mutual commitment across actors, which may turn into symbiotic business models and the creation of a shared culture (Mortensen and Kørnøv, 2019; Pakarinen et al., 2010; Doménech and Davies, 2011; Chertow and Ehrenfeld, 2012).

As the emergence phase unfolds and the EIP becomes populated by actors that develop more complex forms of cooperation, the nature of existing critical factors gradually changes, and new critical factors are added. Obviously, *policy and regulation* remain important as creators of stimuli for EIP development, but as actors discover more potential for symbiotic relations, they become more sensitive to the effect of policy and regulations. A possible *"lack of legislative incentive"* can inhibit the emergence of symbiotic relations (Wahrlich and Simioni, 2019, p. 1476). Similarly, as the EIP develops, the development becomes more sensitive to "urban policy and leadership" as a creator of space and framework for further development (Belaud et al., 2019, p. 983). *Planning* for the EIP during the emergence phase becomes focused on striking a balance *"between industrial development and the quality of urban life"* (Tellier et al., 2019, p. 130), where different zones are dedicated to different types of industrial and urban use. Finally, the availability of *skilled labor* is an important constraint to EIP emergence (Wahrlich and Simioni, 2019, p. 1477), and local employment policy schemes may be needed in order to support EIP development during the emergence phase.

Regarding the presence of other firms, the *diversity of firms* involved in the EIP becomes increasingly important, also when designing a process for revitalizing existing industrial areas (Coté and Cohen-Rosenthal, 1998). A high degree of diversity creates more opportunities for symbiotic relations (Taddeo et al., 2012), and examples show that *"symbiotic exchanges are more likely to occur in an industrial park with several industries"* (Faria et al., 2021, p. 18). If there are plenty of firms, more opportunities for supplying and reusing waste and by-products come about, provided that the firms know of each other's operations and understand how these fit into the operation of the entire EIP (Wahrlich and Simioni, 2019). Diversity may increase due to the presence and activities of large firms, which attract smaller firms in the same industrial region (Maynard et al., 2020), thus stimulating the demand for symbiotic relations.

The role of *geographical location* gradually changes as the EIP develops and more firms are included in the pool of symbiotic relations, or existing symbiotic relations become more elaborate and complex. Co-location facilitates the flow of information between co-located firms, enables business interactions, and thus provides an impetus for the development of trust. The development of trust can be amplified by the availability of various platforms where members can share information, knowledge, and experience. These can take the form of social and professional hubs, councils, forums, etc. (Faria et al., 2021, p. 19). Furthermore, the ties between firms become stronger as *"energy cogeneration, cascading use of resources, and shared services"* unfold during EIP emergence (Faria et al., 2021, p. 19f).

The *governance* by which the EIP emerges is important to how robust the EIP is and how it develops. According to Côté and Cohen-Rosenthal (1998), EIPs are mainly engineered systems or self-organized systems. Both types may appear in actual EIPs, but one or the other is normally the prime driver of the development process. Across the literature, it is often argued that the most robust EIPs are self-organized systems because they are driven by market dynamics, and that EIP failure can be attributed to top-down approaches lacking incentives for individuals and distorting the price mechanism (Costa et al., 2010; Tao et al., 2019). Côte and Cohen-Rosenthal (1998), Verguts et al. (2016) and Gibbs (2009) highlight the success of self-organized systems as opposed to planned systems, although little empirical evidence is presented. However, Bellantuono et al. (2017) show that EIPs developed through top-down initiatives with a high degree of heterogeneity, characterized by the presence of collaborative networks among firms and with governmental agencies, anchor tenants, and shared services, are more likely to adopt a wider range of sustainability practices. Contrarily, EIPs developed through a bottom-up process with a low degree of heterogeneity and characterized by weak support and cooperation with government agencies, are less prone to extensively adopt sustainability practices. Furthermore, a planning-oriented approach to EIP development seems to create robustness to the extent that the EIP development is stimulated by public planning and policy measures that create a coordinating structure (Farel et al., 2016) and set clear objectives supporting eco-efficiency (Tao et al., 2019). Adopting a more flexible approach, Verguts et al. (2016, p. 27), based on the findings from their study of Koekhoven, argue that planned and self-organized EIPs *"cannot easily be separated from each other, because elements of both types of IS development can be identified"*. In the case of Koekhoven, what started out as a planned initiative was taken over by the firms themselves and driven further. In consequence, Verguts et al. (2016, p. 20) advocate that facilitated, middle-out processes are a *"continuum between planned and emergent change."*

What we may infer from this is that what is probably important is not the origin of the governance itself, but *"to create a cooperative environment"* (Faria et al., 2021, p. 19f) that can foster a range of initiatives driving EIP development. Costa and Ferrão (2010, p. 985) suggest that *"a favorable context for IS development can be shaped through an interactive process wherein government, industries, and other institutions are guided towards aligning their strategies in* support *of collaborative strategies in resource management."* This involves a community-based planning approach (Conticelli and Tondelli, 2014), including engaging the *local community* in designing and developing the EIP (Côté and Cohen-Rosenthal, 1998; Taddeo et al., 2017).

4.2.3. Phase 3: probation and its critical factors

The probation phase is the phase where the first signs of an EIP appear, based on the increasing diversity of firms, and the established and emergent flows. The previously emergent flows are physically established, learning accumulates and spreads out to other actors in the system, and actors continue to interact to foster a fruitful context for new emergent symbioses. Benefits and impacts of established flows are analyzed, collaboration and interaction are maintained, and new flows emerge.

The phase of probation is characterized by an increasing awareness among firms regarding the benefits of symbiotic relations, where the benefits are assessed and evaluated along with environmental impacts. This leads to further development of the same or new flows, where information is exchanged to support the maintenance of interactions (Belaud et al., 2019). Mortensen and Kørnøv (2019) describe this situation as a "post-emergence" phase, while Belaud et al. (2019) and Dai et al. (2022), respectively, talk about an "operation phase" and an "organizing" phase. The main characteristic is that the EIP evolves from a small portfolio of symbiotic flows to a network of flows, transforming an industrial site into an eco-industrial site where more and more firms are established, and more and more symbiotic linkages appear (Costa and Ferrão, 2010). This implies that the diversity of actors and the complexity of the industrial system increase (Pakarinen et al., 2010), coordinated by an external facilitator or by decisions made by cooperating firms, where middle-out processes seem especially conducive to EIP development (Costa and Ferrão, 2010). As argued by Doménech and Davies (2011, p. 290), the probation phase "*constitutes a first step in the development of embeddedness for a selected group of actors among which exchange ties have taken place. The experience of cooperation generates trust and 'learning by doing', decreasing the risk associated with further exchanges*."

Regarding *diversity*, the number of firms increases during the probation phase, and so does the heterogeneity and pool of resources available in the local context. *Relationships between public and private actors* proliferate, as public and private actors utilize their assets to arouse interests among each other, promoting business opportunities (for private firms) and regional development (for public organizations). Cross-organizational contacts and know-how are especially important during this process (Uusikartano et al., 2022). The proliferation of symbiotic relations is positively influenced by successful collaboration. This often involves a long-term relationship based on information exchange and the formulation of a shared strategic vision (Noori et al., 2020) that is situated in a context of networking and collaboration, presenting the EIP as *"a community and not just co-located businesses"* (Gibbs and Deutz, 2005, p. 463). Cooperative relationships that optimize resources may occur as clustering along a whole value chain, or one or more firms may function as an anchor tenant attracting more firms, thus expanding the set of definable possible interconnections (Schlarb, 2001). Attracting firms may intentionally target firms that exhibit "*certain desirable characteristics […] to ensure that companies fit with the aims of the development prior to location*" (Gibbs and Deutz, 2005, p. 460).

Symbiotic relations within an EIP depend on *trust and social ties* to a higher extent than ordinary supply chain relations (Ashton, 2008). The proliferation of symbiotic relations does "*not develop from random occasions*" (Zhu and Ruth, 2014, p. 42) or only from policy intervention (Gibbs and Deutz, 2005, p. 463), but seem to arise from increased social contact, e.g., "*in forums, clubs, councils, and associations*" (Zhu and Ruth, 2014, p. 19f). While this leads to an increase in the number of symbiotic relations with "*no clear, linear order in which the actors developed symbiotic relationships*" (Faria et al., 2021, p. 18), it also leads to the development of trust and social ties, because participation and interaction in social events, networks, clubs, etc. encourages communication and information sharing, which in turn "*reinforce relationships of trust and cooperation*" (Faria et al., 2021, p. 19f).

Facilitators can play an important role in the probation phase regarding inter-firm networking by using a variety of methods to activate firms. This may include networking, park-wide environmental management systems and environmental management schemes (Gibbs and Deutz, 2005), and initiatives that address the challenge of identifying opportunities (Mileva-Boshkoska et al., 2018). How firms create value through symbiotic relations is sensitive to the need of coordination (Fraccascia et al., 2017), and for that reason facilitators are often required to engage in the entire process, including implementation (Park et al., 2018). To facilitate the proliferation and further development of symbiotic relations, the facilitator needs to possess a variety of skills, including social skills that are necessary to connect with firms and matchmake them (Patala et al., 2020).

4.2.4. Phase 4: development and its critical factors

The development phase is the phase where the EIP either extends based on the previous probation phase, or where development stagnates or even terminates.

During the development phase, actors such as public organizations and firms still shape the EIP context, e.g., by modifying relevant policy schemes, or by adjusting their actions based on the outcome of EIP operations. The development phase resembles the "adjusting" phase described by Dai et al. (2022) for the transformation of industrial areas into EIPs, and the "operating" and "renewal phase" suggested by Belaud et al. (2019) where increased collaboration and information exchange take place. This *"enables the participating businesses to discuss the synergies' performance and inherent risks, […] circulate information"*, creating *"a trust context between stakeholders and mobilizes the involvement of new actors"* (Belaud et al., 2019, p. 976). This is in line with the "regional learning" phase proposed by Baas and Boons (2004, p. 1077), where "*based on mutual recognition and trust, firms and other partners exchange knowledge, and broaden the definition of sustainability on which they act*." As emphasized by Baas and Boons (2004, ibid.), other stakeholders, like grass root movements, may become involved in the EIP with the effect that "*both goal and range of membership broaden*."

In this phase, the industrial system reaches the type 3 system described by Pakarinen et al. (2010), where *"material flows are almost cyclical: waste is used as a resource for other system components, therefore little waste leaves the system"* (ibid., p. 1394). However, not all EIPs follow the same development path. EIP development may lead to *"expansion"* through renovation of existing connections (Belaud et al., 2019), embeddedness and institutionalization (Chertow and Ehrenfeld, 2012), and forming sustainable industrial districts (Baas and Boons, 2004) as mentioned above. EIP development may also lead to *"stagnation"* and/or *"termination"* (Doménech and Davies, 2011), *"abandonment"* by which firms and other actors leave the system (Castiglione and Alfieri, 2019), or even experience a *"collapse of industrial ecosystems"* (Chertow and Ehrenfeld, 2012), e.g. when a central actor leaves the EIP (Wang et al., 2018). Which of these scenarios occurs depends on the critical factors that characterize the development phase.

The future development of an EIP depends on the ties between actors and is affected by *"changes in the processes and relationships among companies. Therefore, it is necessary to plan or redesign industrial symbiosis complexes to mitigate the risks created by these changes"* (Zhang et al., 2015, p. 99). However, doing this is a double-edged sword. While Wang et al. (2022) and Zhang et al. (2015) suggest that new firms should be

included in the EIP with the purpose of strengthening relationships among incumbent firms, Doménech and Davies (2011) call for caution, because adjustments or changes in processes, use of materials, and management procedures etc. affect the existing and new symbiotic relations. So, the introduction of new firms into the EIP requires that the new firms fit in with both existing and new networks within the EIP.

Coordination and facilitation are still crucial to the EIP evolution. Zhu and Ruth (2014, p. 38) emphasize the role of facilitating institutions that can mitigate market risk and increase the resilience of the system by distributing "*IS activities among firms, which are less likely to lose the whole function of resource efficiency under market disruption*" (ibid., p. 43). Tessitore et al. (2015) call for an EIP management body that can represent the interests of the EIP during consultations with stakeholders, manage EIP infrastructure and processes, and organize the socioeconomic activities such as training, public events, and marketing. While there is a consensus on the importance of facilitation, there is less clarity concerning who or what the facilitating body is. Faria et al. (2021, p.19f) suggest that the ideal governance structure *"should involve local government, companies, R&D institutions, and a coordinating entity or champion."* Tessitore et al. (2015) refer to the municipality, while Heeres et al. (2004) emphasize the role of private business. Uusikartano et al. (2022) reject the dichotomy between private and public agencies and advocate that EIP development always relies on an interplay between a variety of actors.

Whether or not an EIP will continue to exist and flourish, or will stagnate or even terminate, depends on how resilient the EIP is to changes and disruption. This has led researchers to propose that *continuous monitoring* of the EIP network development is essential. Mileva-Boshkova et al. (2018) develop an elaborated model to be used by decision makers and comprising a variety of environmental, technological, organizational, economic, and social factors. Wahrlich and Simioni (2019) advocate an industrial symbiosis indicator tool, while Pakarinen et al. (2010) propose several sustainability indicators to be used for measuring EIP sustainability. Tellier et al. (2019) adopt a more qualitative approach, suggesting that EIP sustainability can be improved through sustainable urban planning and architecture, shared services for employees (such as restaurants, childcare, and car-sharing platforms), and collaboration between firms focusing on joint logistics, joint research, office renting, and energy substitution synergies.

5. Implications for EIP replication and reproduction

To answer this study's research question—How should phases of EIP evolution and their critical factors be considered when replicating or reproducing existing EIP successes to new contexts?—it is necessary to discuss the findings in section 4 through the lens of EIP replication and reproduction. What has been learned from the phases of EIP evolution that can enrich the replication and reproduction process of an EIP? Which recommendations can be given to relevant actors and interested in (i) sharing their successful EIP evolution experiences (replicator perspective) and those interested in (ii) designing and implementing new EIPs through replication and reproduction of an existing one (replicatee perspective)? These are some questions that are addressed in the following discussion.

EIP evolution is found to arise from the emergence and accumulation of several symbiotic relations, which is in line with Doménech and Davies (2011) and seems to follow some of the same developmental phases as the emergence of symbiotic linkages (Mortensen and Kørnøv, 2019) connecting at a higher level of complexity to create a symbiotic network or an EIP. Some of the same critical factors mentioned by Mortensen and Kørnøv (2019) are found to play a role in the EIP evolution.

The findings of this study invite one to think that fostering critical factors is the key to successful EIP development, and that these should be replicated in the new context. However, what is to be replicated and reproduced? What is the knowledge, information, experiences, business models, collaboration models among the local actors, the organization of the EIP coordination body, or the industrial fabric of the area? Mapping the evolutionary process of an EIP and connecting it to its diffusion to a new context, a modular approach to replication (Tsvetkova et al., 2015), seems to be necessary. Within this, the critical factors may function as the various modules that need to be examined and addressed in the new context. Initiatives targeting specific 'system modules', or critical factors can be set in place for the EIP to emerge and develop. Some of these may be replicable without changes from one context to another, but most of the critical factors are expected to be adjusted to the new context.

When replicating or reproducing an EIP pre-emergence in other contexts the following appears to be of great importance. First, the *characteristics and specificities of the new context*. The *geographical, historical, and institutional environment* present some specific opportunities, whilst also presenting challenges for symbiotic relation and EIP emergence.

Each EIP has its own specific history, origin, and geographical and institutional characteristics, which determine the start and continuation of the evolutionary process: its pre-emergence point of time, its emergence pace, its probation characteristics, and its further development. This can also influence its replication process. When reproducing an EIP development into a new context, the new EIP emerging and developing starts to show its own specific characteristics that may be different from the initial EIP. The development of the new EIP disconnects from the replicator EIP, following its own evolutionary path. Within this, a need for modifying and adjusting the institutional environment to match and respond to the changes in society may appear, as this is part of the VUCA (volatile, uncertain, complex, and ambiguous) environment within which industrial developments take place (Millar et al., 2018).

As the (geographical and institutional) contexts of the initial and the new EIP are different, actors differ as well, they present different skills and have different resources. Thus, the symbiotic network is expected to present local characteristics from an early phase of evolution. A focus on these, and thus adaptation of the critical factors' characteristics from the EIP of origin in a diffusion process is necessary. Sakr et al. (2011) argues that there is a need for balancing the local (economic, technical, political, etc.) resources, skills and capabilities if EIP coming about should succeed. This confirms the fact that an EIP cannot be replicated without adaptation, but merely reproduced through adaption to the local characteristics.

When designing a new EIP through reproduction, several aspects need to be analyzed: what is to be found in the new context, is the new EIP to be designed from scratch from a greenfield area or is it to emerge from an existing industrial park from which new symbiotic relations can emerge? Are there any industry, firms, and local business in the neighborhood? Who are these and how many? What relations are there already between these? What types and how much (input/output) resources do these have/need? Neighboring to other companies, industrial parks, or even cities among which symbiotic relations can emerge in time, presents a pool of resources that can be the foundation for the first emergent symbiotic relations from which EIP can emerge and develop.

A thorough analysis and mapping of the strengths and weaknesses of the local geographical, historical, and institutional context regarding e.g., economic, environmental, technical, cultural, financial, political, and history of collaboration present the first inputs to the EIP development. Special attention to be given to the existing (or the need for adjusting) policy and regulation, and the economic incentives to secure eco-industrial development. If shortcomings in these contextual factors are present, EIP development is challenged, and initiatives to create a fostering environment should be set in place.

However, should the characteristics of the new context be compared with the original context? And should one make anything possible to replicate the original context into the new or should the EIP of origin only inspire the new EIP development? An adaptation approach to reproduction implies inspiration and know-how transferring from one

context (of origin) to the new one, seeking empowering of the local actors involved in the process.

Empowerment, agency of and commitment from the local community and actors are found to be of critical importance. While it is the replicator EIP that can provide inspiration and know-how, it is the actors in the replicatee context that are expected to have the responsibility of driving their own development. A relation of empowerment, going from the existing, mature EIP towards the new context is to be established and exchanges of information, know-how, and experience must take place. IS literature refers to capacity building (Spekkink, 2013) and this must take place in the replicatee context including the mobilization and activation of the existing capacity, building it further into curated initiatives towards EIP formation. Furthermore, various *collaborative initiatives* ensure these can be set in place. Initiatives must also target both (i) increasing the number and diversity of the companies in the planned EIP, as these create more symbiotic opportunities; and (ii) securing the planning frameworks for the EIP. A community-based planning and infrastructure development that can accommodate existing and future symbiotic developments is necessary.

While these learnings from the EIP evolutionary process are evident, who is to analyze and map the characteristics of the new environment? Who is to identify and monitor the critical factors' adjustment and set initiatives in place to secure a fruitful environment for EIP development in the new context? A general consideration of who is to be involved from the replicator side in the EIP development, and who is to be the driver of the process, must be made. Also, consideration of the roles of the different actors, and the collaboration among these to create a shared facilitation function must be given. The human resource aspects are mentioned in the organizational and management literature as being of importance when replicating business models to a new context (Winter and Szulanski, 2001). The findings of these studies confirm this and raise the question of the skills of the existing human resources in the new context and the need to secure the necessary skilled labor for the companies, besides strengthening e.g., the economic and policy and regulation environment.

As found through this study, to secure the emergence of initial and new symbiotic relations in the new context, there is a need for *a strong presence of a governance (collaborative) entity*. This may not simply be one actor, but instead a collaboration among various relevant actors with the aim of facilitating the symbiotic relations among companies. Together, through collaboration, these can improve the institutional context creating a more fruitful environment for the initial symbiotic ties. The presence of *a governance entity or a coordination body*, who will initiate a focused process, activate relevant actors, and highlight the existing capacity in the context is crucial. A middle-out approach is found to be the most relevant approach to governance, through which (spatial, resource, etc.) planning, curated facilitation, and firm initiatives integrate into a common evolution. Relevant actors must be involved in the process, including the (civil) community around the industrial area in development, to secure a common vision and development plan.

What is probably most important in EIP development is that the governance entity takes *a strategic approach to development*, and designs relations through clustering along a value chain or/and ones that revolve around an existing or new firm as the anchor tenant in new symbiotic exchanges. Focus should be on how to create diversity that creates resilience in the new EIP, by increasing the number and diversity of firms in and around the EIP area, so that the pool of resources and symbiotic exchanges can increase. The governance entity should initiate measures to attract companies to the newly developed area, and organize collaborative platforms where various private and public actors can interact to maintain and secure the fruitful context for further symbiotic network development. Such platforms should accommodate initiatives to exchange information and formulate and revise the shared strategic vision.

A community view on the symbiotic network in the EIP should be applied. Initiatives for inter-firm networking and ones that contribute to developing and maintaining trust and social ties should be organized regularly. Regularly measuring the effects and benefits of symbiotic relations in specific and the network in general, learning from existing cases and network development should encourage the governance entity to share and increase the EIP community members' awareness of them being part of the network and building on the benefits of shared symbiotic ties. Evidence exists that increased awareness of benefits breed more symbiotic relations (Schlüter et al., 2020).

To *organize platforms* that can foster various initiatives with variate focuses demands diverse skills from a facilitator (Schlüter et al., 2022). Therefore, while focusing on the symbiotic network and community development, the governance entity in the replicate context must also turn the view on its own development, paying attention to the necessary and missing skills, and reach out to relevant partners for collaboration to fill skill gaps for the benefit of the entire EIP.

Later in the EIP development process the facilitation entity can become a *formalized EIP management* body to represent EIPs interests in negotiations, consultations, etc.; manage EIP infrastructure development; organize socioeconomic activities, such as trainings, public and private events, marketing, etc.; and provide continuous monitoring of the EIP network to secure system resilience. The governance entity must secure organization of platforms fostering trust, information and experience exchanges, and provide regular sustainability checks of the system (with well-defined indicators), to secure the long-term development of the symbiotic network and its sustainability in time.

Furthermore, if challenges appear, then initiatives with inspiration from the previous EIP must be put in place in the new EIP through actor collaboration and managed by a central governance and facilitation body to address and solve these challenges. However, should these be replicated and reproduced without regard to the cost, and instead with a focus on the 'health' of the symbiosis in the EIP? Or is there a financial cut off point for the actors involved where the benefits of the replication or reproduction of an EIP are no longer desirable? For example, human resources are more difficult to replicate than technical solutions. Thus, some critical factors might be idiosyncratic and impossible or very costly to replicate. Some factors might be replicable, but detrimental or unrelated to success in the new EIP, e.g. because of differing cultural and legislative factors in the new context. Therefore, the adaptive and flexible approach to reproduction should not only include an investigation of which factors (i) are beneficial to replicate and critical also in the EIP replicatee's context, but also (ii) how possible these are to replicate and how costly reproduction is compared to its benefits. A strong collaboration between the replicator and replicatee, where empowering takes place, might be the key here.

6. Conclusion and avenues for future research

The occurrence and evolution of EIPs is a phenomenon that seems to proliferate across the world and, as a consequence, is becoming a topic of increasing scholarly and managerial interest. The reason for the establishment of EIPs is that firms, public organizations, and to some extent also various actors shaping local communities realize the benefits of creating local productive ecosystems that contribute to green transition by sharing, optimizing, and creating new sources for the use of resources through collaboration.

Because EIPs are becoming increasingly important, they also become a source of inspiration and learning across communities and nations. Therefore, as indicated by the title of our paper, we set out by asking: Can we replicate eco-industrial parks? The answer to this question is that we can replicate EIPs in some cases, but in other cases the creation of EIPs requires adaption to contextual circumstances. The global scholarly interest into how and when these different situations occur points to various phases of evolution characterized by different types of dynamics. Our paper aimed at synthesizing current knowledge by answering the research question: How should phases of EIP evolution and their critical factors be considered when replicating or reproducing

existing EIP successes to new contexts?

By systematically reviewing EIP research focusing on process models, the present paper finds that a multitude of empirical EIP examples are present in the world and described in a rich body of literature. This confirms the statement of Ehrenfeld (2004) and show that with the emergence and development of EIPs around the world, the industrial ecology research field and community of practice continue to evolve and being institutionalized.

Through the systematic literature review it was found that EIPs evolve through four main phases: Pre-emergence, emergence, probation, and development. It is possible to show that each of these phases has its own characteristics and dynamics. Even though phases can be identified, the process of evolution is not linear; it is instead an iterative one, where critical factors are key in forming a fruitful context for EIP evolution. The critical factors comprise the local historical, geographical, and institutional context; the presence of governance or a coordinating body; collaborative interactions among actors and various types of agency; and commitment activated through mobilized capacities. While critical factors persist throughout the phases, they undergo qualitative changes as EIPs grow and evolve. This is caused by an increasing degree of diversity and complexity of the EIP, where actors and agency become embedded as interactions and ties multiply and intensify. As the studies analyzed in this literature review rely on real-life cases to different extents and few of them are analyzing EIPs in-depth across their development phases, a systematic comparison of these critical factors across EIP cases requires further collection of empirical data, which might represent an ambition for future research to verify and further elaborate our developed framework of EIP evolution.

So, when embarking on creating an EIP, either through greenfield establishment or brownfield transformation, the involved actors need to reflect on the characteristics of local context as compared to the context from which the creation of EIP is inspired. The replicator of an EIP must be aware of the differentiating character of its own development process to make sure that knowledge is properly diffused and activated in the new context. This must be based on a willingness to share know-how and to empower the actors in the new context for their own EIP development. The replicatee must be aware of the local historical, geographical, and institutional context, and how the context frames opportunities for evolution. Acting on this awareness requires a governance or coordination body that takes a strategic and community approach to EIP development, and which becomes gradually formalized as the EIP travels through its phases of evolution. Governance and coordination must provide collaborative platforms to involve and align local actors in collaborative initiatives, the purpose being to foster commitment to symbiotic relationships that can proliferate and become increasingly diverse.

These reflections on replicator and replicatee roles and behavior leads us to suggest three avenues for future research.

First, as the study of replication is scarce in the EIP literature, it might provide value to connect EIP research with research fields on knowledge transfer, capacity building, etc. Literature and theories within these fields can provide strong insights on the aspects of replication that can then be studied in the context of EIP evolution.

Second, research should be directed towards unfolding the span of reproduction and replication. This includes conceptualization of e.g., types such as technical, organizational, spatial, and sectoral diffusion, and the distinction between routine versus non-routine diffusion. Also, transferring knowledge, expertise, and best practices from one existing EIP to a new context requires an effective diffusion mechanism and capacity-building initiatives. Because there are different diffusion channels through which replication and reproduction can take place, future studies should attempt to explore the potentials of channels such as promoting awareness, supporting research, and training—and the significance of whether it is facilitated diffusion or not.

This paper discussed replication as one strategy of developing EIPs, based on a model of EIP evolution outlining critical factors of the process. Zooming out, there could be value in comparing a replication strategy with other strategies for EIP development (e.g. those characterized by strong policy incentives or complete top-down planning) and to contrast how they differ in terms of effectiveness or how they might complement each other for the development of successful EIPs.

Finally, an existing EIP seems to engage in several important activities when replicating its concept to a new context, such as providing knowledge, offering technical assistance, building capacity and training, fostering networking and partnership, and serving as a learning platform for the recipient. Future research should tackle the question of which roles a replicator can play in relation to the recipient of knowledge and learning (the replicatee), and what it entails to become an active facilitator of their own EIP replication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

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Appendix A. Selected articles and their use in this study

#	Article	Used for building analytical framework	Sorted into EIP evolution phases	Discarded in 2nd iteration
1	The industrial symbiosis process as an interplay of public and private agency: Comparing two cases. Uusikartano J., Saha P., Aarikka-Stenroos L. (2022).		x	
2	A synthesised framework of eco-industrial park transformation and stakeholder interaction. Dai Y., Day S., Masi D., Gölgeci I. (2022).	x		
3	Industrial Symbiosis at the Facility Scale. Mulrow J.S., Derrible S., Ashton W.S., Chopra S.S. (2017).			x
4	Supply chain collaboration in industrial symbiosis networks. Herczeg G., Akkerman R., Hauschild M.Z. (2018).			x
5	Business models for industrial symbiosis: A taxonomy focused on the form of governance. Fraccascia L., Giannoccaro I., Albino V. (2019).			
6	Sustainable manufacturing through creation and governance of eco-industrial parks. Farel R., Charrière B., Thevenet C., Yune J.H. (2016).		x	

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#	Article	Used for building analytical framework	Sorted into EIP evolution phases	Discarded in 2nd iteration
7	The organization of eco-industrial parks and their sustainable practices. Bellantuono N., Carbonara N., Pontrandolfo P. (2017).		x	
8	Eco-industrial parks development and integrated management challenges: Findings from Italy. Tessitore S., Daddi T., Iraldo F. (2015).			
9	Bi-level fuzzy optimization model of an algae-sugarcane-based Eco-industrial park. Aguilar K.D.T., Chiu G.M.K., Ubando A.T., Aviso K.B., Tan R.R., Chiu A.S.F. (2017).			x
10	Intermediation dilemmas in facilitated industrial symbiosis. Patala S., Salmi A., Bocken N. (2020).		x	
11	Facilitating business collaborations for industrial symbiosis: The pilot experience of the sustainable industrial network program in Colombia. Park J., Duque-Hernández J., Díaz-Posada N. (2018).		x	
12	Eco-industrial park initiatives in the USA and the Netherlands: First lessons; Heeres R.R., Vermeulen W.J.V., De Walle F.B. (2004).		x	
13	Institutional lens upon industrial symbiosis dynamics: The case of Persian gulf mining and metal industries special economic zone. Noori S., Korevaar G., Ramirez A.R. (2020).		x	
14	Industrial Symbiosis: towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives. Baldassarre B., Schepers M., Bocken N., Cuppen E., Korevaar G., Calabretta G. (2019).			
15	Industrial ecosystems? The use of tropes in the literature of industrial ecology and eco-industrial parks. McManus P., Gibbs D. (2008).			
16	Modeling and evaluation of the possibilities of forming a regional industrial symbiosis networks. Mileva-Boshkoska B., Rončević B., Uršič E.D. (2018).		x	
17	The Development of Industrial Symbiosis in Existing Contexts. Experiences From Three Italian Clusters. Taddeo R., Simboli A., Morgante A., Erkman S. (2017).		x	
18	Energy-based industrial symbiosis: a literature review for circular energy transition. Fraccascia L., Yazdanpanah V., van Capelleveen G., Yazan D.M. (2021).			
19	A critical review of symbiosis approaches in the context of Industry 4.0. Scafà M., Marconi M., Germani M. (2020).			
20	Towards sustainable business parks: A literature review and a systemic model. Le Tellier M., Berrah L., Stutz B., Audy J.-F., Barnabé S. (2019).		x	
21	Eco-industrial parks: Stimulating sustainable development in mixed industrial parks. Lambert A.J. D., Boons F.A. (2002).		x	
22	Designing eco-industrial parks: the US experience. Cohen-Rosenthal Edward (1996). Replaced with: Côté, R.P. & Cohen-Rosenthal, E. (1998), "Designing eco-industrial parks: a synthesis of some experiences"		x	
23	Understanding the organization of industrial ecosystems: A social network approach. Ashton W. (2008).		x	
24	Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site. Taddeo R., Simboli A., Morgante A. (2012).		x	
25	Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: The role of contextual factors. Simboli A., Taddeo R., Morgante A. (2014).		x	
26	Industrial symbiosis dynamics, a strategy to accomplish complex analysis: The Dunkirk case study. Morales M.E., Diemer A. (2019).		x	
27	Eco-industrial parks and sustainable spatial planning: A possible contradiction? Conticelli E. and Tondelli S. (2014).		x	
28	Effect of policy on industrial symbiosis: Simulation study from the perspective of enterprise operation. Wang L., Zhang Q., Wang H. (2022).		x	
29	The influence of policy on industrial symbiosis from the Firm's perspective: A framework. Tao Y., Evans S., Wen Z., Ma M. (2019).		x	
30	Waste management policies for industrial symbiosis development: case studies in European countries. Costa I., Massard G., Agarwal A. (2010).		x	
31	Efficacy of landfill tax and subsidy policies for the emergence of industrial symbiosis networks: An agent-based simulation study. Fraccascia L., Giannoccaro I., Albino V. (2017).		x	
32	The development of regional collaboration for resource efficiency: A network perspective on industrial symbiosis. Zhu J. and Ruth M. (2014).		x	
33	A review of industrial symbiosis research: theory and methodology. Zhang Y., Zheng H., Chen B., Su M., Liu G. (2015).		x	
34	Industrial symbiosis in Taiwan: Case study on Linhai industrial park. Maynard N.J., Vaishnav Raj K. S., Hua C.-Y., Lo S.-F. (2020).		x	
35	Implementing industrial ecology? Planning for eco-industrial parks in the USA. Gibbs D. and Deutz P. (2005).		x	
36	Social, economic, and institutional configurations of the industrial symbiosis process: A comparative analysis of the literature and a proposed theoretical and analytical framework. Faria E., Caldeira-Pires A., Barreto C. (2021).		x	
37	Industrial symbiosis as sustainable development strategy: Adding a change perspective. Verguts V., Dessein J., Dewulf A., Lauwers L., Werkman R., Termeer C.J.A.M. (2016).		x	
38	Sustainability and industrial symbiosis-The evolution of a Finnish forest industry complex. Pakarinen S., Mattila T., Melanen M., Nissinen A., Sokka L. (2010).	x	x	
39	A case study of industrial symbiosis development using a middle-out approach. Costa I. and Ferrão P. (2010).	x	x	
40	Industrial symbiosis in the forestry sector: A case study in southern Brazil. Wahrlich J. and Simioni F.J. (2019).		x	
41	A circular economy and industrial ecology toolbox for developing an eco-industrial park: perspectives from French policy. Belaud J.-P., Adoue C., Vialle C., Chorro A., Sablayrolles C. (2019).	x	x	
42	Backward snowballing: Additional articles referenced in the above articles and (partly) included Schlarb, M. (2001). Eco-industrial development: A strategy for building sustainable communities. CITED IN: Conticelli and Tondelli (2014), p. 337			

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#	Article	Used for building analytical framework	Sorted into EIP evolution phases	Discarded in 2nd iteration
43	Chertow, M., and Ehrenfeld, J. (2012). Organizing Self-Organizing Systems. Journal of Industrial Ecology, 16 (1), 13–27. CITED IN: (Tao et al., 2019)	x	x	
44	Doménech, T., and Davies, M. (2011). The role of Embeddedness in Industrial Symbiosis Networks: Phases in the Evolution of Industrial Symbiosis Networks. CITED IN: Zhu and Ruth, 2014	x	x	
45	Jelinski et al. (1992) CITED IN: Pakarinen et al. (2010)	x		
46	Mortensen, L., and Kørnøv, L. (2019). Critical factors for industrial symbiosis emergence process. CITED IN: Dai et al. (2022)	x		
47	Baas, L. W., and Boons, F. (2004). An industrial ecology project in practice: Exploring the boundaries of decision-making levels in regional industrial systems. CITED IN: Fraccascia et al. (2019).	x		

Articles that were neither used for building the analytical framework, sorted into phases, nor discarded, were used as background knowledge and for writing the introduction of this article.

Appendix B. Phases of EIP network development according to literature (Basis for analytical framework)

Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
Baas and Boons (2004)	regional industrial ecology/EIP (brownfield and greenfield)	Draws on literature on organizational change, institutionalization, the lifecycle concept, evolution of collective good producing organizations, Community development, and Incrementalism to build the phases and uses the framework to analyze the case of the Rotterdam harbour and industry complex		3–4	0) Selection	Only found in greenfield development. This stage "precedes these three phases. In the selection phase, the actors that will form the core of the socio-technical system are selected. This selection can involve criteria related to the process of sustainable development." (Baas and Boons, 2004, p. 1077,)
					1) Regional efficiency	"autonomous decision-making by firms; co-ordination with local firms to decrease inefficiencies (i.e. 'utility sharing'). Such activities may be facilitated by local government authorities, existing co-operative arrangements between entrepreneurs, in short: local social networks. This phase is characterized by identifying and make use of existing win–win situations." (Baas and Boons, 2004, p. 1077)
					2) Regional learning	"based on mutual recognition and trust, firms and other partners exchange knowledge, and broaden the definition of sustainability on which they act. In this phase, other stakeholders (local citizens, grass roots movements) may become involved as well. Thus, both goal and range of membership broaden." (Baas and Boons, 2004, p. 1077)
					4) Sustainable industrial districts	"actors develop an—evolving—strategic vision on sustainability and base their activities on this vision." (Baas and Boons, 2004, p. 1077)
Chertow and Ehrenfeld (2012) [which was also cited in (Zhu and Ruth, 2014, p. 38)]	IS	"drawing upon work by three research teams. Schwarz and Steininger (1997)[…] Baas and Boons, […] Chertow and Ehrenfeld" (Chertow and Ehrenfeld, 2012, p. 19)	"the boundaries between the stages may be fuzzy in practice" (Chertow and Ehrenfeld, 2012, p. 19) "the stages are discontinuous, the progress across them is nonlinear and cannot be predicted" (Chertow and Ehrenfeld, 2012, p. 19)	3	1) Sprouting	"Firms begin to exchange resources on a random basis for a variety of reasons. A limited network of interlinked flows takes shape (Schwarz and Steininger, 1997). Chertow (2007). refers to the initial exchanges as "kernels" of industrial symbiosis that face a market test and, even when

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Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
						successful, may or may not lead to further exchange activity. Schwartz and Steininger add the argument that the positive network externalities created may change decision analysis in firms such that new exchanges become desirable. Up to this stage, standard market-driven industrial organizational theories apply.“ (Chertow and Ehrenfeld, 2012, p. 19)
					2) Uncovering	“The realization that some networks have created positive environmental externalities becomes consciously revealed or “uncovered,” typically through the observations of an actor whose focus is beyond the private transactional network (Chertow, 2007). Baas and Boons (2004) associate this stage with regional learning where both goals and range of membership broaden” (Chertow and Ehrenfeld, 2012, p. 19)
					3) Embeddedness and institutionalization	“[…] later stages having more intentional and institutional realization of positive environmental externality” (Zhu and Ruth, 2014, p. 38) “In addition to self-organization, further expansion of the network becomes intentionally driven by an institutional entity created at an earlier stage that becomes more deeply established during this stage. As for how long this might last, we have evidence that industrial symbioses can persist over many decades, as is the case of Kalundborg, Denmark, and Kwinana, Australia, but still little information about the collapse of industrial ecosystems.” (Chertow and Ehrenfeld, 2012, p. 19)
Doménech and Davies (2011)	EIP	Based on analysis of three cases: NISP, Kalundborg, Sagunto		3	1) Emergence	“A first phase in the development of IS networks is the emergence of the network. Some main conditions seem to characterize the contexts where IS emerge (Domenech and Davies, 2009). The conditions are the following. (I) Stringent and rapidly evolving regulatory frameworks. (II) Waste-flow exchanges require customized, non-standard, applications or involve an innovative component or approach, and, therefore, imply uncertainties with regards to the outcomes and process. (III) As a result of the need for customized solutions, high coordination is required, which implies frequent interaction between companies, favouring the transfer of tacit knowledge, ‘learning by doing’ and the creation of a shared culture or ‘macroculture’ (Jones et al., 1997). In this first phase, initial ties are developed and some straightforward cooperation opportunities explored. Generally, these first

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Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
						ties do not require complex transformation processes, technological upgrades or innovation, but they set the basis of the dynamics of cooperation. The formation of the network may be the result of a spontaneous process, like the network in Kalundborg and Sagunto, or be initiated by a policy actor, as in the case of NISP." (Doménech and Davies, 2011, p. 288)
					2) Probation	"The next phase in the development of IS networks is the probation phase [...]. At this stage, network members have a general knowledge of the dynamics of the network and the opportunities of potential exchanges and cooperation. First experiences of exchanges have generated and feedback from them permeates the network, through more or less informal channels that might vary from comments from members in informal meetings to more formalized accounts of the experiences such as publication of case studies. This phase is crucial, as failure in the realization of the opportunities may lead to the early collapse of the initiative. The probation phase constitutes a first step in the development of embeddedness for a selected group of actors among which exchange ties have taken place. The experience of the cooperation generates trust and 'learning by doing', decreasing the risk associated with further exchanges." (Doménech and Davies, 2011, p. 290)
					3) Development	"Building on the experiences of the probation period, the network enters a phase of development and expansion (see igure 7) by the building of new linkages and/or the deepening of the existing relationships. Continuous interaction and accumulation of experiences of cooperation allow the thriving of embedded ties, governed by trust, tacit knowledge and joint problem-solving, and generate routines of cooperation that significantly reduce the transaction costs associated with it. More experiences of interaction increases the possibilities of further potential exchanges (a) by widening the material and knowledge basis of the system and (b) through the mechanisms of referral and transitivity (assuming that the referred parties will behave cooperatively), which favour the identification of other potential linkages and actors, deepening the level of embeddedness of the

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Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
						network as a whole." (Doménech and Davies, 2011, p. 291)
Pakarinen et al. (2010) refers to Jelinski et al. (1992)	EIPs evolution	Case: The framework is based on Jelenski et al. (1992) and it is used to analyze an ISN around a pulp and paper mill in South-Eastern Finland	While Jelinski and colleagues "just" describe these systems as different types, Pakarinen refers to them as stages of a system, indicating a process towards type 3 system. In their case they observe a process from type 1 to type 3.	3	1) Type 1 system	A system in which "the potentially useable resources [are] so large and the amount of life so small that the existence of life forms ha [s] essentially no impact on available resources. This individual component process might be described as linear-that is, as one in which the flow of material from one stage to the next is independent of all other flows." (Jelinski et al., 1992, p. 793) "Type I is an undeveloped system in which processes are linear" (Pakarinen et al., 2010, p. 1394)
					2) Type 2 system	a "contrasting picture [to a type 1 system] is an ecosystem in which proximal resources are limited. In such a system, the resulting life forms become strongly interlinked and form the complex networks we know today as biological communities. In this system, the flows of material within the proximal domain may be quite large, but the flows into and out of that domain (i.e., from resources and to waste) are quite small." (Jelinski et al., 1992, p. 793) "much more efficient than the previous one, but it clearly is not sustainable over the long term because the flows are all in one direction, that is, the system is "running down."" Jelenski, p. 793 "In Type II a few [cyclical] flows exist but the degree of exchange is still limited." (Pakarinen et al., 2010, p. 1394)
					3) Type III system	"To be ultimately sustainable, biological ecosystems have evolved over the long term to be almost completely cyclical in nature, with "resources" and "waste" being undefined, since waste to one component of the system represents resources to another." (Jelinski et al., 1992, p. 793) This is a type 3 system. "In Type III material flows are almost cyclical: waste is used as a resource for other system components, therefore little waste leaves the system." (Pakarinen et al., 2010, p. 1394 " […] where new actors in the symbiosis utilized wastes from previous actors and produced useful by-products thus increasing the connectivity and complexity of the system" (Pakarinen et al., 2010, p.1396)
Dai et al. (2022)	Ageing industrial areas repurposed to EIPs	Literature review, drawling heavily on Mortensen and Kørnøv (2019)			1) Covering	'Stakeholders spontaneously carry out cooperative activities without deliberate long-term planning or an agreed end-goal; the background of EIP development is created ' (p.6)

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Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
					2) Awareness	'Driven by the actions of external stakeholders like governments and research institutions, firms become aware of the benefits of participating in an EIP transformation project' (p.6)
					3) Connecting	'Potential partners share information and improve understanding; prepare for the decision of joining the project and first goals are set' (p.6)
					4) Organizing	'Exchange linkages and symbiosis networks are planned, and the decision by firms is made; these linkages and networks are then established' (p. 6)
					5) Adjusting	'Governments modify the relevant policy, and firms, adjust their actions based on outcomes of EIP operations' (p. 6)
Mortensen and Kørnøv (2019)	IS	Literature review			1) Awareness and interest	where "the collaborative, co-creational processes, also described by Spekkink and Boons (2016) as preceding the collaborative process, can create an awareness of and interest in the economic and environmental benefits generated through IS relations" (Mortensen and Kørnøv, 2019, p. 61).
					2) Reaching out and exploration of connections	the development of trust, bridging actors, and facilitators are in focus
					3) Organizing	the role of funding, policy, and infrastructure is more pronounced, to implement the symbiotic linkages (Mortensen and Kørnøv, 2019)
Belaud et al. (2019)			They show the process as a cycle, indicating that it is not a linear process.	5	1) Design phase	integration of EIP into the design of the industrial area. The existing infrastructure as e.g. "water, energy and support services" (p. 974) is a requirement. "Therefore, the EIP project plan has integrated the decision of the installation of energy and industrial water networks." (p. 974)
					2) Layout phase	the authors refer to the actual development of the infrastructure, where excavation and soil removement was done. 'The programming of public works contracts has integrated land movements so that the generated soil flows can be stored within the park area before their total reuse.' (p.975)
					3) Commercialization phase	during this phase exploration of possibilities and data management for new symbiosis were performed. Activities such as: 'process analysis was performed to determine the necessary project improvements.' 'industrial flow data management to identify and create potential synergies.' (p. 975) Data management and shared info on waste flows available was performed 1) by a third party: 2)

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Source	Context	Basis for developing the phases	Characteristics of the process as a whole	# of phases	Phases	Characteristics of the phases
						information shared at the common meetings/networking meetings between companies.
					4) Operating phase	interconnected companies, 'gain benefits from the new efficient services created throughout industrial synergies and waste management' (p. 976), 'flow assessment and the evaluation of synergies' impacts', 'companies' collaboration and their information exchange should be continuously maintained', environmental risk assessment is detected' (p. 976)
						'The collaboration in the EIP initiative makes the exchange of information between involved companies possible. It enables the participating businesses to discuss the synergies' performance and inherent risks. This approach ensures a trust context between stakeholders and mobilizes the involvement of new actors. The settled strategy is to monitor the environmental performances during the operating phase and to largely circulate the information.' (p. 976)
					5) Renewal phase	'The renewal phase aims to anticipate the main modifications within the system functioning. Therefore, it enables updating of the project scheduling according to each case specificities and planning of the associated refurbishment works.' (p. 976)
						- 'involves the opportunities of the infrastructures deconstruction, their recycling, the artificialization of soils, etc. The associated method for this phase is ongoing Development.' (p. 976)
						The authors present the tools for commercialization phase. 'This model [...] reorganizes many activities and gathers them in three main activities, namely market research, application analysis and finally decision-making.' (p. 978)

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