A synthesised framework of eco-industrial park transformation and stakeholder interaction

Authors and institutional affiliations

Yuxi Dai[a], Steven Day[b]*, Donato Masi[c], Ismail Gölgeci[d]

[a] WMG, University of Warwick, Coventry, United Kingdom
[b] School of Management, Zhejiang University, Hangzhou, China
[c] Aston Business School, Aston University, Birmingham, United Kingdom
[d] Department of Business Development and Technology, Aarhus University, Aarhus, Denmark

*Corresponding author.
Postal address: School of Management Building A, Zhejiang University, 866 Yuhangtang Road, Hangzhou, 310058 China
Email address: sjday@zju.edu.cn
Telephone: 0086 158 0581 1404

Abstract

Eco-industrial parks (EIPs) combine the concepts and principles of industrial ecology (IE) and industrial symbiosis (IS) to enable environmentally-friendly industrial manufacturing capacity. The current reality is that many EIPs are developed from ageing industrial parks (IPs). However, how such EIP transformation projects are managed by diverse public and private stakeholders is largely unknown. This study summarises the results of a systematic literature review (n=61) to identify a five-stage process of EIP transformation. Five key stakeholders and influencing factors are identified, and drawing on process theory, a framework is developed that highlights how these stakeholders work together over time. While this study serves as an overview of the body of knowledge on the business and social aspect of EIP transformation, the main contribution of this work is the propositions on the interactions and order of stakeholders embedded in the framework, which can guide future research especially on the early stages of EIP transformation. In practice, EIP project managers can judge the stage of the project based on the project status and work back from actions entities undertake to progress the project systematically.

Keywords: Eco-industrial parks, industrial ecology, industrial symbiosis, transformation project

1. Introduction

Eco-industrial parks (EIPs) are groups of co-located firms that form partnerships to exchange resources to increase resource utilisation and reduce environmental impact (Bai et al., 2014). EIPs are increasingly popular: currently, there are about 250 self-styled EIPs operating worldwide, with a third in non-OECD countries, while fewer than 50 existed in 2000 (World Bank, 2018). An example of such an EIP is South Korea's Ulsan Mipo and Onsan Industrial Park (Park et al., 2008; Park and Won, 2007), which achieved $554 million in eco-related savings by 2018 (World Bank, 2018).

Previous research on EIP can be classified into two main research streams. A first stream analyses EIPs from a firm or value chain perspective, characterising processes for the emergence of industrial symbiosis (IS) (Mortensen and Kørnøv, 2019), the role of information-sharing platforms in facilitating by-product exchanges (Fraccascia and Yazan, 2018), the trust required for firms to commit to such processes (Ramsheva, Prosman, and Wæhrens, 2019), or the environmental and economic benefits of IS exchanges (Chertow and Miyata, 2011). A second stream adopts a macro perspective (e.g., Park, Park, and Park, 2016; Yu, Dijkema and de Jong, 2015), analysing government policy and the outputs of national EIP development programs, and particularly the role of incentives in driving EIP development (Heeres, Vermeulen and de Walle, 2004). While both streams have expanded significantly over the last decades, also due to renewed interested in IS as part of the circular economy research agenda (e.g., Kanda, Geissdoerfer and Hjelm, 2021; Tseng et al., 2022), individual studies are couched within their local and national circumstances and focus on particular actors, processes, and factors while using different terminologies and methodologies. Many studies on EIP transformation describe individual examples in detail through well-designed and executed case studies (e.g., Côté and Liu, 2016; Taddeo, Simboli and Morgante, 2012; Xu et al., 2017). But transferring this insight to a more general level is difficult without considering other cases

spread throughout the literature. Other work considers individual factors such as the technological underpinnings of achieved outcomes but struggles to illuminate the preceding organisational transformation that allows firms to agree to energy and material exchanges in the first place (e.g., Taddeo, 2016). Other studies consider several relevant factors but do not order them chronologically (e.g., Chen et al., 2017; Fan et al., 2017), which clashes with assertion transformation projects' dynamics change over time (e.g., Mortensen and Kørnøv, 2019).

This fragmentation in the EIP literature may be caused by its transdisciplinary scope covering sustainability research, industrial engineering and development, and business and project management; the result is that a systematically developed, integrative framework on how IPs may be transformed into EIPs is currently lacking. This is a significant issue for research as we are at risk of failing to build on the rich findings that exist in the literature and progressing knowledge meaningfully through consolidation, which hampers practice as lessons from previous EIPs transformation projects are not systematically studied and carried over into the future. We, therefore, ask the following research question:

How do stakeholders of EIP transformation projects successfully engage at different points in time?

We answer this question through a systematic literature review (SLR) of the existing literature on EIP transformation projects. There is a rich and varied knowledge base in our field that is relevant to our research question. To build on this literature without replicating it, we thus integrate existing findings to form a framework connecting key stakeholders and their activities, as well as other influencing factors, at different points in time in an EIP transformation project. Our framework particularly builds on Mortensen and Kørnøv's (2019) model of IS emergence, and we utilise a process theory perspective to analyse previous literature and structure our results.

The article is structured as follows. Section 2 presents the fundamental constructs and theories that feed into our analysis of the literature. In Section 3, the applied review methodology is described. Section 4 first presents a brief descriptive analysis of the reviewed articles before coming to the thematic analysis of the studies that describe the (1) five stages of our process framework, (2) five stakeholders for EIP transformation, and (3) enablers and barriers underpinning the transformation. Section 5 summarises our work and highlights the study's contribution to knowledge on EIP transformation, suggests future research themes and describes the limitations of our work.

2.1 Background

2.1 Types of EIPs transformation project and influencing factors

Before we proceed to the SLR on EIP transformation, we define the main constructs of our study that feed into the analysis. These constructs relate to the types of EIP transformation projects, the key stakeholders in EIP transformation projects, and the types of factors that determine the success of these projects.

In line with previous literature (e.g., Costa and Ferrão, 2010; Farel et al., 2016), we distinguish between two broad types of EIP based on the impetus behind their development. The EIP of Kalundborg (Denmark) is described as the first EIP that illustrated the principles of IS in practice and was established through the initiative and self-organisation capabilities of firms already co-located in an IP (Chertow, 2007). We classify such EIP transformations as "bottom-up" projects as firms already co-located in an existing IP or with access to a suitable brownfield site for further development self-organise, with government support provided only after the the initial establishment of the symbiosis network (Desrochers, 2001; Valentine, 2016).

The second type of EIP transformation project has been more frequently observed in recent years. In such projects, for example, in China and Egypt, IS principles are actively supported and promoted through government policies and agencies (Fang, Côté and Qin, 2007; ElMassah,

2018a). While firms ultimately retain decision-making power over the establishment and management of exchanges, governmental stakeholders play a significant role in bringing firms to consider the potential of EIP transformation and may provide further support as the project progresses (Costa and Ferrão, 2010). For example, the Egyptian government's desire to implement the sustainable development goals (SDGs) is reflected in its industrial development policy and government-faciliated EIP programme (ElMassah, 2018b). We classify these projects as "top-down" as the projects are facilitated by governmental stakeholders and are typically part of wider industrial modernisation and sustainability initiatives. Such projects may be conducted with firms in existing IPs and/or on brownfield sites, or new projects on greenfield sites (Heeres, Vermeulen and de Walle, 2004).

In line with previous research (Hewes and Lyons, 2008; Ramsheva, Prosman and Wæhrens, 2019), we propose that EIP transformation projects of both types are conducted by a range of key stakeholders. These key stakeholders possess agency and pursue agendas that are not necessarily aligned to those of the other stakeholders, which evolves through EIP transformation projects because of engagement with other stakeholders and the presence or absence of further influencing factors.

We further conceptualise that the success of both "bottom-up" and "top-down" projects are impacted by various factors, which previous studies have explored to varying degrees in different contexts (Boons and Spekkink, 2012; Sakr et al., 2011). These factors can take the form of an enabler when conducive to a project's success or barrier when detrimental to a project's success. For example, Park et al. (2008) proposed sufficient technical and service support as an enabler of the South Korean EIP programme and EIPs' self-management and -improvement capability. However, at the Borg El-Arab Park (Egypt), a lack of innovative technological capabilities hindered the further development of the exchange network (ElMassah, 2018a). Influencing factors may therefore act as enablers or barriers in different

contexts or at different points in time of the EIP transformation project. We define the influencing factors based on our analysis of the literature in Section 4.

2.2 Process theory approach to EIP transformation

Furthermore, our research framework draws on the process theory of change (Langley et al., 2013; Pentland, 1999). Process theory is among the key theories explaining change and transformation in socioeconomic entities (Kunisch et al., 2017). The main premise of the process theory is that it specifies a "process model that lays out a set of mechanisms explaining events and subsequent outcomes" (Cornelissen, 2017, p3). Such models allow explaining how different phenomena emerge, evolve, or terminate over time through interconnected and path-dependent activities and events. Thus, it captures the richness of change processes that socioeconomic entities go through (Cloutier and Langley, 2020). Process theorising thus results in a system of ideas that explains how an entity changes and develops (Langley et al., 2013). Such a system includes (1) a clear sequence of the beginning, middle, and end in time, (2) focal actors, (3) the explanation of the phenomenon through focal actors' viewpoints, (4) an evaluative frame of reference, and (5) indicators of context over time and place (Pentland, 1999). At the same time, it requires moving "(1) from variables to events, activities and trajectories; (2) from entities to dynamic entanglements; (3) from correlation to contingent interaction; (4) from outcomes to potentialities; and (5) from predictions to generative mechanisms" (Cloutier and Langley, 2020, p4). Process theorising is particularly relevant for moving from description to explanation and producing knowledge on the procedural changes that occur in a system while transforming (Langley et al., 2013). It lays out, articulates, and helps explain transformation processes that are experienced by different socioeconomic entities.

Accordingly, we conceptualise EIPs as a socioeconomic entity undergoing a transformation process and adopt process theory to study and elaborate EIP transformation in this study. As the process theory facilitates explicating mechanisms and stakeholders involved in change

(Cornelissen, 2017) and how a certain phenomenon evolves over time (Cloutier and Langley, 2020), it is a useful theoretical approach in our study in the pursuit of developing a framework where key stages and stakeholders involved in EIP transformation are delineated and explicated.

3. Methodology

A systematic literature review methodology following Denyer and Tranfield's (2009) suggestions was employed to mitigate author bias and achieve more replicability than traditional narrative-based reviews. Guided by the overarching research question and following an iterative process based on an initial scoping study that reviewed several highly relevant studies to identify concepts of interest to this paper (Tranfield, Denyer and Smart, 2003), the authors formulated more specific review questions to guide the data collection and analysis:

a) Who are the key stakeholders in EIP transformation projects?
b) Which enablers and barriers determine EIP transformation?
c) How do these enablers and barriers impact EIP transformation?
d) At what point in time do these enablers and barriers exert influence?
e) Which key stakeholders own enablers and barriers at different times?

Relevant studies were located in academic databases using search strings and Boolean operators. As shown in Table 1, two groups of keywords concerning "industrial parks" and "transformation" were identified. Synonyms and closely related concepts were included in these two groups, as is common in published systematic literature reviews (Suppatvech, Godsell and Day, 2019). Four databases (ABI/INFORM Global, EBSCOhost Business Source Complete, Scopus, ScienceDirect) were chosen to cover EIP research. Keywords were transformed into search strings, which were applied to the title and abstract searches of journal and conference papers to capture the resurgence of EIP research driven by a renewed interest in sustainability and CE-associated concepts in particular (Ghisellini, Cialani and Ulgiati,

2016). Where possible (e.g., ABI/INFORM Global) these keywords were applied from January 2000 to December 2020; where databases prevent specifying search windows to months (e.g., Scopus), we applied these to the full years of 2000 to 2020.

Table 1: Search strings applied to different academic databases (by authors).

Databases	**Industrial parks**		**Transformation**	**Number of results**
ABI/INFORM Global	ab(“industrial park” OR “industrial symbiosis” OR “industrial ecolog*” OR “eco-industrial park” OR “industrial zone” OR EIP)	AND	ab("transf*" OR "transformation project" OR "transformation program*" OR develop*)	437
EBSCOhost Business Source Complete	AB (“industrial park” OR “industrial symbiosis” OR “industrial ecolog*” OR “eco-industrial park” OR “industrial zone” OR EIP)		AB ("transf*" OR "transformation project" OR "transformation program*" OR develop*)	332
Scopus	ABS(“industrial park” OR “industrial symbiosis” OR “industrial ecolog*” OR “eco-industrial park” OR “industrial zone” OR EIP)		ABS("transf*" OR "transformation project" OR "transformation program*" OR "develop*")	2,931
ScienceDirect	Title, abstract or author-specified keywords: (“industrial park” OR “industrial symbiosis” OR “industrial ecolog” OR “eco-industrial park” OR “industrial zone” OR eip)		Title, abstract or author-specified keywords: ("transf" OR "transformation project" OR "develop")	291

In the initial search result, a total of 3,991 English articles written were retrieved, including 3,303 academic papers and 688 conference papers. After deduplication, the total number of articles was reduced to 2,911. Subsequent screening for content relevance was performed in three steps: journal screening, title and abstract screening, quality screening, and full-text screening. The first and second authors determined screening criteria by randomly choosing 50 articles of the 2,911 articles, reading titles and abstracts, and then inducing criteria. These criteria were refined by the second round of random selection and induction after the quality screening. These refined criteria are shown in Table 2.

Table 2: Inclusion and exclusion criteria (by authors).

Criteria		**Aims**	**Justification**
Inclusion	Publications since 2000	To capture all relevant knowledge on the topic is captured	The "newer" generation of CE-induced EIP, especially in developing countries, can be assumed to be different from earlier examples.
	Papers on industrial ecology, industrial parks, environmental management, industrial development, sustainable development, etc. from all over the world	To ensure that all potentially relevant areas are included as long as they focus on what are essentially EIP transformation	Jointly determined based on the main research question and review questions
Exclusion	Non-English language papers	To avoid misunderstandings	Authors' language abilities
	Articles in journals in unrelated areas	To ensure the articles that are selected are related to the transition projects and of high, peer-reviewed quality	The research content of those does not intersect with this research
	Articles in journals rated lower than 2 in AJG 2018 (or conference publications)		
	Papers talking about the operation of EIPs and sustainability evaluation indicators	To make sure that the reviewed articles can provide information on the transition phase of EIPs and not only the operational phase	Although the operation of an EIP is affected by its previous transition period, inferences from one to the other would be unreliable

First, the initial set of publications was screened according to the subject area. 993 publications were removed as they were published in unrelated journals or conferences. Afterwards, as common in SLRs in business management (e.g. Aguinis, Ramani and Alabduljader, 2018; Hällgren, Rouleau and de Rond, 2018; Nguyen, de Leeuw and Dullaert, 2018), the authors implemented additional quality criteria as shown in Table 2, after which 625 publications

remained. The second phase of the screening process commenced by looking at titles and abstracts. This was done by the first author; borderline cases were given to the second author and then discussed to decide on in- or exclusion. A similar process was followed for the subsequent full-text screening, resulting in 45 articles as shown in Figure 1. A further 16 articles were included by scrutinising the references used in those 45 articles and including articles that were cited frequently or highly relevant to our work, for which we relaxed in- and exclusion criteria.

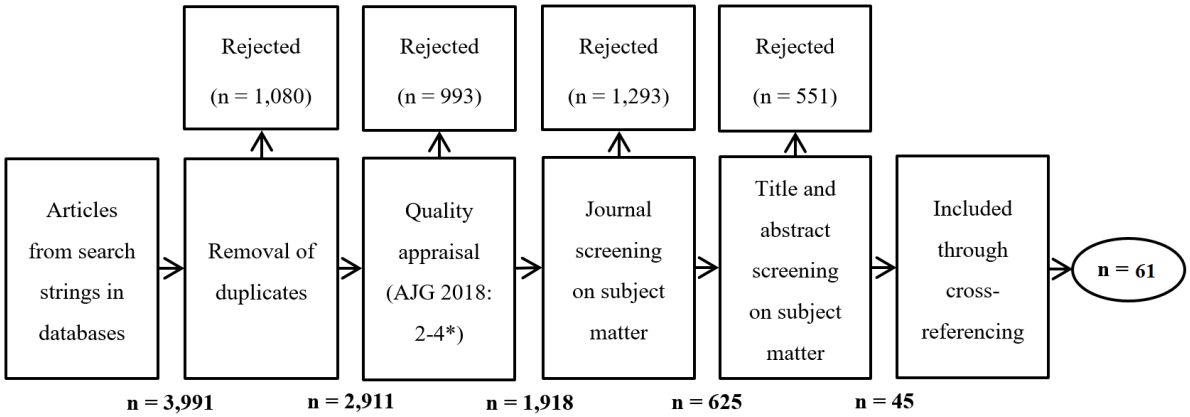


Figure 1: Schematic diagram of the publication selection process (by authors).

The analysis of the 61 selected articles (shown in Table A.1 in the Appendix) consists of a brief descriptive analysis to trace the development of the EIP transformation literature, and a longer thematic analysis occupied with the review questions. This thematic analysis is based on a data extraction sheet developed by the first two authors based on an inductive approach and the work of Mortensen and Kørnøv (2019). The sheet was first structured according to the review questions and then refined by the authors after reading five random articles in-depth to capture all pertinent information (Suppatvech, Godsell and Day, 2019). During this reading, codes were generated by both authors, which were then individually sorted into groups. These groups were then discussed and named by the two authors, and the revised version of the data extraction sheet was then applied to all 61 papers by the first author.

4. Results

4.1 Descriptive analysis

An initial descriptive analysis reveals that the body of knowledge on EIP transformation has expanded over the last two decades and Figure 2 shows that there remains heterogeneity in the types of published articles. Before 2004, studies on EIP transformation looked primarily at the IS concept as illustrated by the Kalundborg EIP and how it could be applied to foster a new generation of sustainable production zones through conceptual discussion and narrative reviews of previous sustainability-related literature. The number of case studies on EIP transformation projects increased after 2004, and such work remains consistently valuable as scholars explore the impact of different contexts on the success of such projects. Looking at which scholarly outlets have contributed most to the EIP transformation literature, Figure 3 shows that environmental- and sustainability-oriented journals such as the *Journal of Cleaner Production* and the *Journal of Industrial Ecology* publish the bulk of work, although a total of 15 journals have contributed articles.

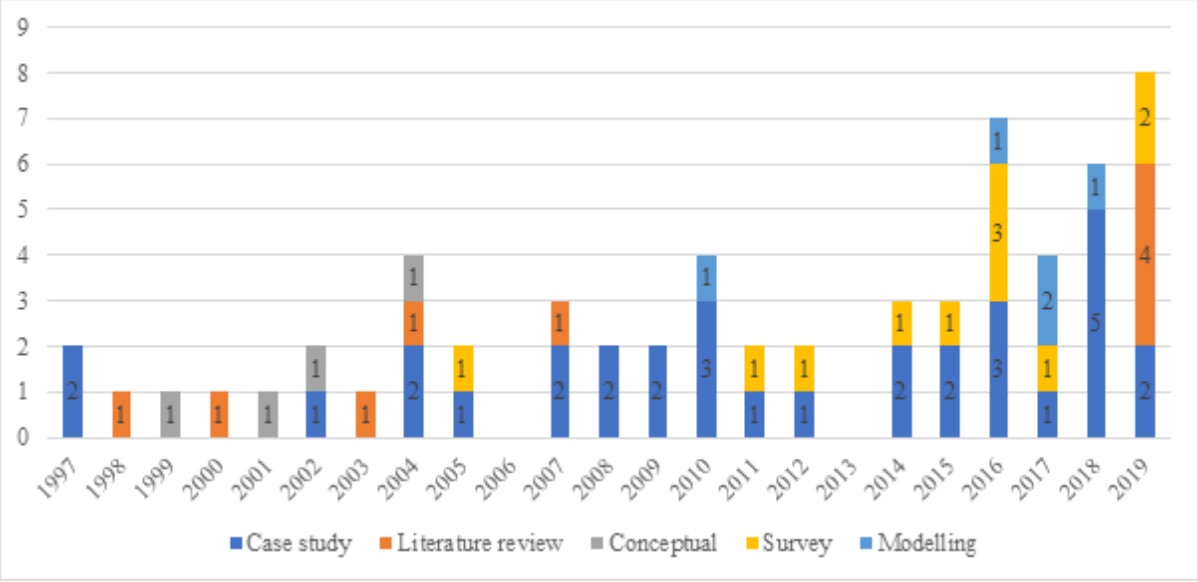


Figure 2: Types of articles published in different years (by authors).

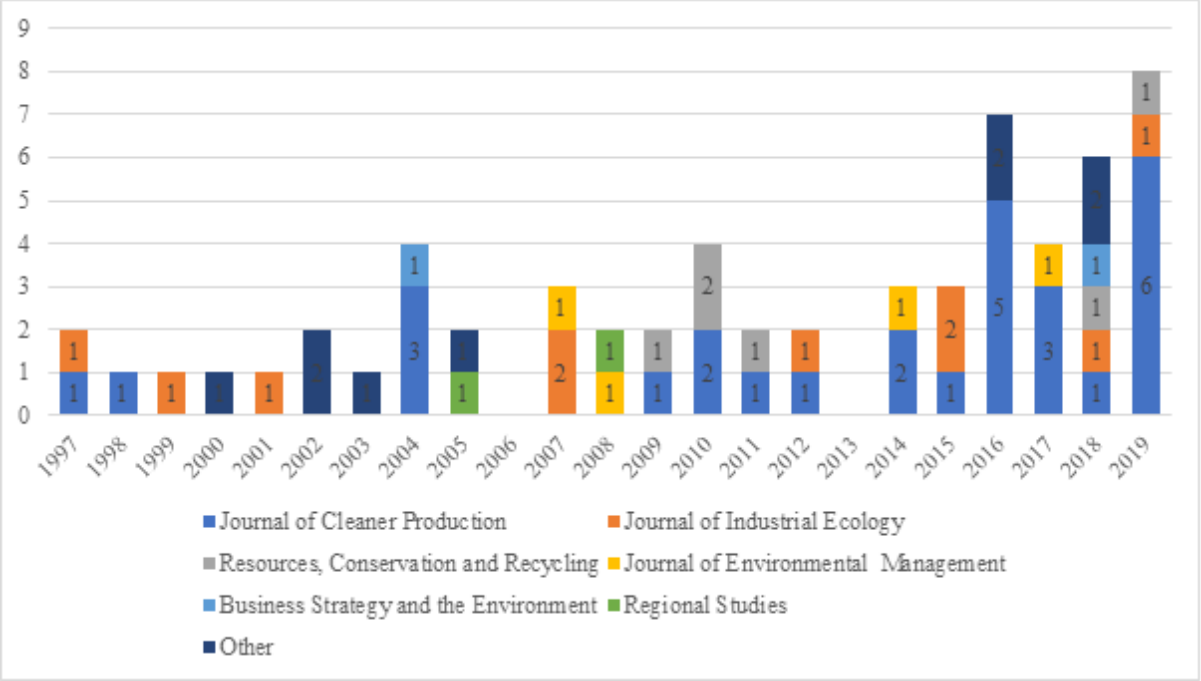


Figure 3: Types of journals in which articles were published in different years (by authors).

Describing our sample of papers further, we find that EIPs or closely related concepts have been studied in various countries, most often China, followed by South Korea and Denmark (see Figure 4). Interestingly, several studies utilise samples from several countries to compare and contrast EIP transformation in different contexts (e.g. Farel et al., 2018). Last, we describe the main contributions and limitations of the articles in Table A.1 in the appendix, which reveals that studies have struggled to consider the complexity of multiple stakeholders and how they interact over time in EIP transformation projects.

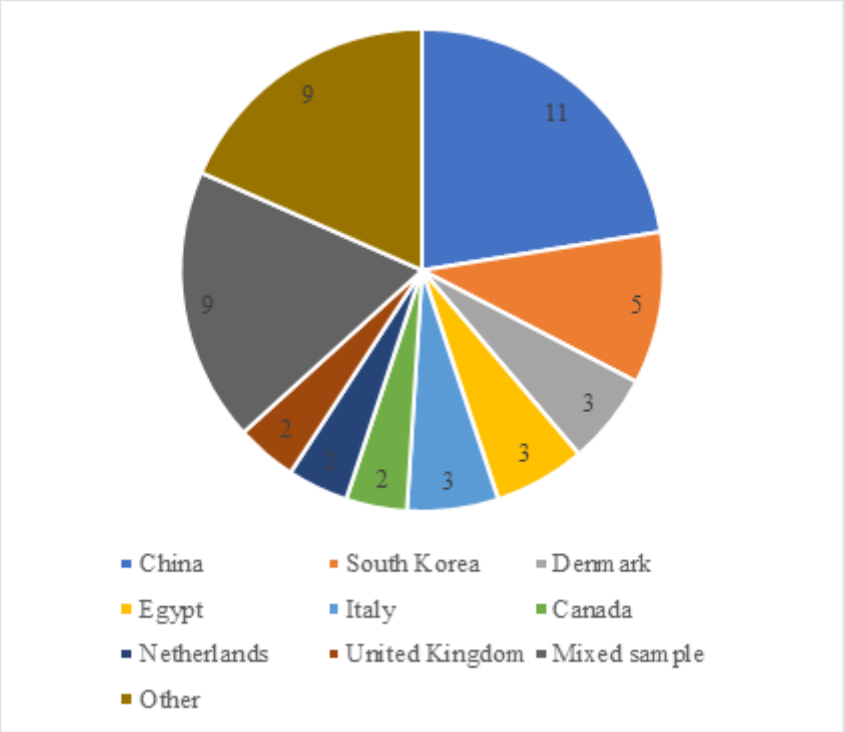


Figure 4: Geographic context of published articles (by authors); note that numbers do not add up to 61 since not all studies refer to particular geographic contexts.

4.2 Thematic analysis

The thematic analysis is split into three parts: (1) the five stages of the EIP transformation process, (2) an overview of the key stakeholders, and (3) influencing factors of EIP transformation projects. A final synthesis combines these three parts into a framework.

Process of the EIPs transformation project

Based on the patterns observed in the publications and iterative induction and re-analysis of the data, EIP transformation projects can be divided into five process stages: *Covering, Awareness, Connecting, Organising, and Adjusting*. This represents an expansion of the three phases that Mortensen and Kørnøv (2019) proposed and differs from Costa and Ferrão's (2010) work on interventions to create favourable EIP development conditions. This study instead looks beyond the initial linkages themselves to the success of the resulting EIP as an emergent

entity using a process theory perspective. Table 3 defines each process, and the following paragraphs detail their function.

Table 3: Definitions of the five stages in the EIP transformation process proposed by this study (by authors).

Stages	**Definitions**
Covering	Stakeholders spontaneously carry out cooperative activities without deliberate long-term planning or an agreed end-goal; the background of EIP development is created
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
Connecting	Potential partners share information and improve understanding; prepare for the decision of joining the project and first goals are set
Organising	Exchange linkages and symbiosis networks are planned, and the decision by firms is made; these linkages and networks are then established
Adjusting	Governments modify the relevant policy, and firms adjust their actions based on outcomes of EIP operations

The initial *Covering* process stage only exists in spontaneous transformation projects that are driven "bottom-up" by the involved firms themselves. Here firms begin established ad-hoc symbiosis exchanges in existing IPs without outside intervention, awareness or formal knowledge of IS, or a third-party facilitator. This is most likely to occur when firms are already co-located or when a regional culture or similar production processes foster relatability (Susur, Hidalgo and Chiaroni, 2019) to make use of unwanted by-products of existing production processes (Desrochers, 2004). *Covering* was observed in the case of Kalundborg, where the executives of firms were engaged in social interactions as part of the local community (Valentine, 2016). Although researchers are aware of this stage, it is difficult to explore in research as it is usually already over by the time investigations start (Van Beers, Bossilkov and Lund, 2009). Kalundborg's EIP transformation, being the most successful spontaneous transformation, is therefore considered non-imitable (Desrochers, 2001; 2004) or at least rare in this first stage (Gibbs, Deutz and Proctor, 2005) as the chances for spontaneously identifying by-product exchange potentials are low (Ehrenfeld and Gertler, 1997). The exact conditions necessary for this network to emerge are largely unknown, although many are likely contextual (Mortensen and Kørnøv, 2019; Valentine, 2016). Research on this stage attempts to understand

the conditions facilitating the spontaneous formation of cooperative activities and material exchange, which in practice lays the groundwork for more sophisticated EIP development.

In the subsequent *Awareness* stage, key firms realise the significance and importance of more holistic and deliberate EIP transformation. This stage usually requires external participants, often governmental authorities or facilitators (Park, Park and Park, 2019) to organise understanding and communication between firms (Taddeo, 2016) and recognise IS potentials (Chertow, 2007). Previous experience in a country or region can help firms understand and buy into EIP transformation (Mirata, 2004). However, usually, this stage is often difficult as the potential benefits of EIP transformation are balanced with a lack of technology, expertise, and/or openness to change in involved firms (Chen, Xu and Zhou, 2017; Sakr et al., 2011) with factors related to uncertainty ranked as the most relevant (Bacudio et al., 2016). Firms who have previously developed exchanges in a "bottom-up" manner realise in the *Awareness* stage that only some of the necessary conditions for the transition to EIP have been fulfilled. Long-term planning and interdependencies are necessary to unlock further exchange relationships (Desrochers, 2001; Ehrenfeld and Gertler, 1997).

In the *Connecting* stage, firms exchange extensive information on potential IS flows, which is likely facilitated by exchange platforms or forums provided by external stakeholders (Fang, Côté and Qin, 2007; Mirata, 2004). In EIPs in Canada (Côté and Liu, 2016) and South Korea (Park, Park and Park, 2019; Park and Won, 2007), external stakeholders were responsible for providing technical support to establish a network platform for information sharing and making recommendations based on the results of inter-firm discussions to ensure that exchanges would be viable in different scenarios. Indicators of success are important for guiding such discussions but difficult to establish as several papers seeking to develop suitable indicators shows (Korhonan and Snäkin, 2005; Tiejun, 2010; Xu et al., 2017). This stage occurs similarly for both "bottom-up" and "top-down" projects and requires a (non-profit) mediator; Yu, de Jong

and Djikema (2014) show that government authorities can move from a planning role to a coordinating and facilitating role from this *Connecting* stage to the next stage.

During the *Organising* stage, the EIP transformation project moves from uncommitted planning to increasingly committed implementation. After the communication between stakeholders in the previous stage, these channels are used to foster commitment and formalise the future of the EIP (Ramsheva, Prosman and Wæhrens, 2019), which may be upset by changes in policy if government authorities are heavily involved in the transformation (ElMassah, 2019b; Veiga and Magrini, 2009) or if several government programmes are involved (Zhang et al., 2010). Integrating the needs and goals of different stakeholders while achieving a substantial IS network is critical here to achieve economic and environmental outcomes (Costa and Ferrão, 2010; von Malmborg, 2004). The main difference between "top-down" and "bottom-up" projects in this stage is that the latter already have commercially viable exchange networks, while the former need external support in terms of policy and finance to form networks. The achievement of tangible economic benefits as the strongest motivator (Yu, Han and Cui, 2015) thus remains conditional on how well the EIP is designed and implemented by the various stakeholders, creating uncertainty (Chen et al., 2017).

The literature shows that EIPs need to be monitored and fine-tuned continuously as exchange networks cannot remain static in a changing environment. This happens in the *Adjusting* stage, where firms continuously recalibrate exchanges. This stage is recognised more often in research on "top-down" projects, even though it may still be challenging to maintain or improve efficiency in "bottom-up" projects as changes may affect various exchange relationships (e.g., Valentine, 2016). For "top-down" planned projects, whether a network can pass the market test is one of the keys to determine whether it can be seen as a successful transformation project, and this may require adjustment (Yu, de Jong and Dijkema, 2014). Interventions by stakeholders other than firms may still be necessary at this stage to ensure

continued viability and exploration of further exchanges (Susur, Hidalgo and Chiaroni, 2019) and achieve long-term continuity for the firms and the environment without trading-off one for the other (Pellenbarg, 2002).

As shown in Table 4, *Organising* has received the most research attention, followed by *Awareness* and *Connecting*. *Covering*, being exclusive to "bottom-up" projects, is discussed less, as most EIP transformations projects were initiated or at least strongly facilitated by local governments or planning authorities.

Table 4: Overview of publications that discuss bottom-up and top-down EIP transformation and the five key stakeholders during the five-stage process of EIP transformation (darker grey colour indicates more publications) (by authors).

	Bottom-up	**Top-down**	**Government authorities**	**Research organisations**	**Boundary spanners**	**Firms**	**Communities**
Covering	(3) (14) (19) (39) (53)					(11)	(46) (53)
Awareness	(3) (8) (14) (39) (53)	(1) (4) (5) (16) (20) (28) (29) (32) (36) (38) (41) (46) (48) (51) (56) (58) (60) (61)	(1) (2) (4) (8) (10) (20) (23) (25) (37) (39) (41) (42) (46) (48)	(2) (10)	(24) (36) (38) (45) (46) (48)	(4) (5) (27) (48)	(31) (37) (46) (47) (51)
Connecting	(8) (26) (39) (53)	(1) (2) (4) (5) (12) (16) (18) (20) (21) (22) (28) (29) (31) (36) (38) (39) (42) (46) (48) (49) (56) (58) (59) (61)	(1) (2) (4) (18) (20) (22) (27) (35) (37) (39) (43) (44) (46) (51) (53) (59)	(10) (12) (27) (37) (38) (41) (42) (47) (48) (53) (61)	(8) (36) (45) (48) (51) (53)	(7) (37) (48)	(31) (35) (47)
Organising	(8) (9) (14) (15) (17) (26) (39) (53) (54)	(1) (5) (10) (12) (13) (16) (20) (21) (22) (23) (24) (28) (29) (30) (31) (32) (33) (34) (35) (37) (38) (39) (40) (41) (42) (43) (46) (47) (48) (49) (50) (51) (52) (55) (56) (57) (58) (59) (60) (61)	(2) (13) (37) (46) (51) (53) (60)	(10) (12) (37) (42) (47) (59)	(6) (12) (21) (22) (24) (26) (37) (40) (43) 48) (50)	(1) (8) (10) (12) (14) (15) (23) (26) (33) (34) (37) (42) (48) (50) (53) (54)	(12) (31) (35) (47) (53) (54) (61)
Adjusting		(10) (16) (34) (48) (49) (52) (59) (61)	(5) (12)	(10) (12) (49)			

Key stakeholders

In addition to the five salient process stages explained above, we identify five key stakeholders who drive the change processes of EIP transformation projects. These stakeholders are government authorities, research organisations, boundary spanners, firms, and communities.

Governments promote the development of EIPs because past industrial development has increased resource consumption and pollution (Mathews, Tan and Hu, 2018; Park et al., 2008). While federal government policy can spur *Awareness* at a national level, the *Connecting* and

Organising stages can be driven by local governments who reconcile national-level strategy and local economic interests (Mortensen and Kørnøv, 2019; Chertow, 2007). EIP transformation projects are therefore frequently initiated by local governmental authorities aligned with national programmes (Bai et al., 2014; ElMassah, 2018a, 2018b) and they are assumed to be the most effective among all stakeholders in driving projects (Mathews, Tan and Hu, 2018; Fan et al., 2017) as they can act themselves as well as facilitate action from other stakeholders (Mirata, 2004). Local governments can serve as information brokers between other key stakeholders and networking platforms for firms and support the central management team of the EIP project during decision-making (Dong et al., 2018; Taddeo, Simboli and Morgante, 2012). Government's financial and advisory support for projects can also spur firms to invest more in transformation projects themselves as risk is spread out (Costa and Ferrão, 2010), and exchanges can be scaled up, further increasing the viability of the EIP (Park, Park and Park, 2019).

Meanwhile, research organisations include universities, technology consulting firms, or internal research departments of firms. Research organisations are critical during the *Awareness* stage as their experience and knowledge of IS and technology can help formulate government policies and goals and create interest among firms (Bai et al., 2014; Costa and Ferrão, 2010). During *Connecting* and *Organising*, research organisations disseminate knowledge of IS to firms in the local contexts (Côté and Liu, 2016; Park, Park and Park, 2016). There are also some research organisations with sufficient capabilities to lead experimental projects through the entire process of transformation (Sterr and Ott, 2004). Research organisations with local industrial networks can collect relevant data from the firms to determine potential synergies (Susur et al., 2019). EIPs may therefore benefit from ties with local universities and spontaneously implement collaborative development actions (Le Tellier et al., 2019). Governmental stakeholders may also provide access to knowledge and technology

or funding when research organisations can effectively network or lobby (ElMassah, 2018a; Fang et al., 2007).

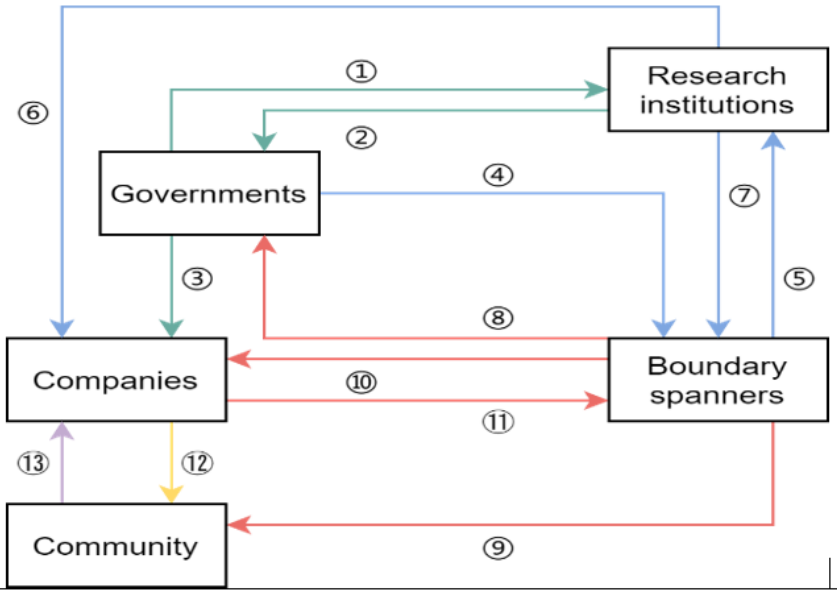
Boundary spanners are agents such as IS champions, central management organisations, or third-party coordination agencies (Ramsheva, Prosman and Wæhrens, 2019; Fang et al., 2007). The purpose of these boundary spanners is to get transformation projects off the ground by building connections between stakeholders and later guide them to further commitment (Susur et al., 2019). During *Awareness*, they mainly organise informal activities to develop social ties between relevant stakeholders as they can gauge potentials with incomplete information based on experience (Ramsheva, Prosman and Wæhrens, 2019) and foster active participation by other stakeholders in the project (Sakr et al., 2010). In spontaneous EIPs, the central management organisation comprises representatives of firms highly interested in participating in the material and energy exchanges (Ehrenfeld and Gertler, 1997; Valentine, 2016). Even if relatively informal, such organisations facilitate the IS network and can convince firms that IS exchanges can be financially viable, not just environmentally beneficial. In "top-down" projects, the central management organisation usually includes several government representatives, researchers and consultants, and firm representatives (Gibbs, Deutz and Proctor, 2005; Fang et al., 2007; Taddeo, 2016), although Sakr et al. (2011) propose that non-governmental champions may be more effective than individuals belonging to governmental authorities. Third-party facilitators can replace central management organisations initially and support their development by promoting links between other stakeholders (Chertow, 2007).

While firms are involved in all stages, the success of the EIP transformation project depends on their belief in the financial viability of their investment in the project during the *Organising* phase (Yu, Han and Cui, 2015). A firm must have a clear picture of the future relationship between the partners in an EIP project (Pellenbarg, 2002). From the perspective of developing "bottom-up" projects, it is usually large firms aware of by-products exchange

potentials from other closely located firms, which anchor the project (Chertow, 1999). In the EIPs of Styria (Austria) and Kalundborg (Denmark), linkages are developed around one or several such anchor tenants. Most of the functions of those core firms are waste acceptors, and cooperation is mainly focused on their needs (Desrochers, 2002). In "top-down" projects, large firms fulfil a similar anchoring function, providing a baseline of exchanges and capability that may attract other firms. Large firms are commonly the core of EIP transformations, homogeneous industrial systems composed of small-medium enterprises (SMEs) may more easily form EIPs in practice due to their agility (Susur et al., 2019). That said, they may require further access to funding to take part in EIPs, particularly when relocation is necessary (ElMassah, 2018b). However, interfirm alliances may be able to alleviate such issues (Chen et al., 2017).

Last, local communities provide a background for EIP development during the *Awareness* stage and act as important stakeholders to reach consensus during *Organising*. EIP projects can bring environmental and economic benefits to local communities. However, there may also be legal and procedural resistance if an EIP transformation project is perceived poorly by the public (Taddeo, 2016; Taddeo, Simboli and Morgante, 2012), which is especially likely if other stakeholders do not engage with communities productively early on (Veiga and Magrini, 2009). For example, public perception of an EIP project in Tianjin, China, suffered from an unrelated industrial accident near the project site (Mathews, Tan and Hu, 2018). Other key stakeholders, particularly governments and firms, are advised to manage the perception of the project early and pre-empt resistance (Zhu et al., 2015), for example, by involving communities in project planning and illustrating the benefits that will accrue to the community (Le Tellier et al., 2019). Communities seem to play a more active role in "bottom-up" than in "top-down" projects where significant public support is seemingly perceived as optional (Hewes and Lyons, 2008).

Figure 5 maps the actions taken by key stakeholders in the network of a "typical" EIP transformation project. While Actions 1, 2, and 3 happen sequentially in *Awareness*, Actions 4, 5, and 6 occur chronologically during *Connecting*. Action 7 usually starts after Action 4, but this is uncertain. In *Organising,* there is no certain order for Action 8, 9, 10, and 11, which may happen simultaneously. Action 12 and 13 can happen in the very early process of the EIP project during *Planning* or at any other stage in the project.



No.	Actions
1.	Seek advice, incorporate them into the EIP project, and provide financial support
2.	Help formulate reasonable environmental policies and make recommendations for revisions based on the implementation
3.	Formulate environmental policies and make them aware of the necessity of industrial transformation
4.	Put forward the goals of the transformation project and provide financial and resource support
5.	Organise communication and training events
6.	Provide IS knowledge, technical support, and feedback on exchange activities
7.	Advise on management knowledge
8.	Develop project execution plan, feedback progress, and seek help when needed
9.	Communicate, spread IS concepts, and build trust
10.	Promote connections between different industries and between firms and other stakeholders
11.	Put forward their needs and information of by-products or waste they can provide
12.	Provide more job opportunities
13.	Support or boycott the firm's local business activities

Figure 5: Diagram of actions between key stakeholders in EIP transformation projects (by authors).

Influencing factors

The factors influencing EIP projects can be divided into policy formulation, database establishment, trust development, capability enhancement, and symbiosis network organisation. In line with process theory, these factors are identified and explained as underlying means of EIP transformation (for an overview, refer to Appendix Table A.2).

Looking at policy formulation, a lack of supportive regulation for EIP transformation and sustainability initiatives more broadly is perceived as a near-universal problem (Massard, Leuenberger and Dong, 2018; Zhang et al., 2010; Zhu et al., 2015). In China and South Korea, a major drive for EIP transformation is stricter environmental regulation, but without further assistance EIPs are often not commercially viable (Fan et al., 2017; Park and Won, 2007). In China, there is a worry that any investments into environmental performance put firms at a cost disadvantage (Chen, Xu and Zhou, 2017). In Italy, the national government gave local governments more power on environmentally friendly industrial development, but the national regulations are still perceived to only marginally support EIP development in practice (Taddeo, Simboli and Morgante, 2012). SMEs, in particular, need additional investment for upgrading capabilities and relocation (ElMassah, 2018b), but governments in various countries may not facilitate funding or loans (Chen, Xu and Zhou, 2017; Park, Park and Park, 2016).

In terms of policy barriers, some interventions have been proposed that broadly fit into Costa and Ferrão's (2010) "middle-out" approach of developing more accommodating contexts for EIP transformation, which mirrors Farel et al. (2016) identification of mixed approaches combining top-down and bottom-up EIP organisation. First, environmental policies should adopt appropriate incentives and maintain flexibility, which can still be impactful in "bottom-up" projects to encourage further exchanges (Valentine, 2016). In "top-down" transformations, government goals and incentives should aim at overall improvements rather than fixed targets to allow firms to go beyond and optimise exchanges and innovative (Côté and Liu, 2016; Park, Park and Park 2019), although Desrochers (2002, 2004) make a case against government planning and for market coordination. Second, forming investment alliances or interfirm alliances involving SMEs in the park and the wider region can help solve some of the funding difficulties (Chen, Xu and Zhou, 2017). Ultimately, most literature proposes that government needs to play a bigger role both in paving access to funds and creating a regulatory environment

that rewards environmentally friendly production and/or punishes non-compliance for creating the conditions for commercially successful EIP transformation (Fan et al., 2017; Massard, Leuenberger and Dong, 2018).

The second factor, information databases, are one of the most crucial enablers in developing EIP projects (Fan et al., 2017; Sterr and Ott, 2004). Databases for recording experiences are usually open, facilitating the collection and analysis of IS information (Zhu et al., 2015). For example, Yeo et al. (2019) propose a database for storing individual reports for firms to enable client firms to understand potential synergy opportunities and benefits. Meanwhile, a database for sharing information about ongoing EIP projects is usually restricted as they store confidential information, but this also means that success cases may remain hidden (Park, Park and Park, 2016; Yeo et al., 2019). Fraccascia and Yazan (2018) argue that worries about confidentiality are often overestimated by firms and make a case for more data sharing to establish IS opportunities.

Desrochers (2001) indicates that some firms would spot opportunities for symbiosis exchanges when using such databases themselves if the information is valid and up to date. However, when databases become large, firms may be overwhelmed (Massard, Leuenberger and Dong, 2018), and without further assistance to interpret information and spot opportunities, regional databases may be unlikely to help EIP transformation (Costa and Ferrão, 2010). To counteract this, databases need to inform potential participants of EIP development opportunities and existing flows in regions; combining material flow data with a geographic information system (GIS) can facilitate this (Yeo et al., 2019). Leveraging the potential of databases may also be easier for firms in IPs that already possess a strong digitalisation background. When the scale of EIPs is large, monitoring existing and potential exchanges and other processes in an EIP requires data analysis capabilities among firms that may not be present in every EIP (Yeo et al., 2019). Furthermore, access to databases and the application

of data analysis tools may also give research organisations and boundary spanners evidence of EIPs' performance and potential to lobby for policy changes (Hashimoto et al., 2010).

Coming to the next factor, stable exchange networks require the trust of the stakeholders, particularly firms (Hewes and Lyons, 2008; Susur, Hidalgo and Chiaroni, 2019) for four reasons. First, EIP transformation payoffs are uncertain from the perspective of firms (Côté and Liu, 2016; ElMassah, 2018a). Private firms may be unwilling to significantly invest in sustainability initiatives (Susur et al., 2019) particularly when immediate benefits are minor and payback periods long (Valentine, 2016). Research organisations and boundary spanners can disseminate commercially successful EIP project cases and create trust in the commercial benefits of EIPs. Second, interdependencies between firms rise through exchange relationships (Ehrenfeld and Gertler, 1997; Gibbs, 2003), and once suppliers fail to maintain flows or the quality of the exchanged by-product varies, the cost for downstream firms can be very high (van Beers, Bossilkov and Lund, 2009; Sterr and Ott, 2004). Interdependence is therefore seen as a risk, and trust is necessary to mitigate it; Boons and Spekkink (2012) find that to be perceived as a credible by-product exchange partner, a firm needs to be believed to possess a high mobilisation capacity. Third, contracts or agreements underpinning EIPs are often complex and not transparent (Park, Park and Park, 2016). It is also hard to predict how goals and interests among stakeholders may shift through the transformation until the EIP becomes stable (Côté and Smolenaars, 1997), making parties reluctant to sign complete long-term contracts that specify material and energy exchange details (Fang et al., 2007). Last, although firms in the same symbiosis network may not consider each other competitors, firms may be weary of sharing confidential information that may benefit IS linkages (Ramsheva, Prosman and Wæhrens, 2019). This reluctance to share information may also extend to other stakeholders such as communities (Gibbs, Deutz and Proctor, 2005). These four factors can be

mitigated by trust and the belief that other stakeholders in the transformation will act collaboratively.

A central project management agency and governmental authorities may create trust by proposing a long-term plan for the EIP transformation project (Le Tellier et al., 2019; Taddeo, Simboli and Morgante, 2012). Implementing low-hanging fruit IS exchanges can foster this trust and build confidence that the EIP can work; such projects require investment but produce visible results in the short term with quantifiable benefits (Valentine, 2016). Communication is another basis for building trust, as various papers show (ElMassah, 2018a; Hwang, Jeong and Ban, 2016; Park et al., 2008). For example, regular meetings with senior-level support can evidence commitment and foster trust that other key stakeholders remain engaged with the project (Taddeo, Simboli and Morgante, 2012). Ramsheva, Prosman and Wæhrens (2019) specify that firms first develop calculation-based trust in the commercial viability of EIPs, then knowledge-based trust from participating in and/or observing successful cooperation, and then identification-based trust as firms' goals and decision-making becomes collectivised, but the function of calculation-based trust is most prominent in the reviewed literature.

The capabilities of countries, parks, regions, and individual firms all significantly impact the EIP transformation project (Zhu et al., 2015; Sterr and Ott, 2004). Limited by knowledge and technical capabilities, SMEs (Susur et al., 2019; Mirata, 2004) or developing countries (Massard, Leuenberger and Dong, 2018) might struggle with EIP transformation.

Some interventions have been trialled to build capabilities; particularly providing financial support to research institutions for disseminating IS knowledge to firms and fund scoping studies among smaller firms (Chen et al., 2017; Park, Park and Park, 2019). Understanding EIPs can promote traditionally separated industrial participants to participate in symbiosis activities collectively (Susur et al., 2019) during *Awareness*. The establishment of joint ventures through cooperation between research organisations and private stakeholders can

disseminate knowledge quickly (Mathews, Tan and Hu, 2018). However, when regions' or countries' technical and environmental management capabilities are insufficient, their assistance to firms may be curtailed (Susur et al., 2019; Fang, Côté and Qin et al., 2007). Then, cooperation with international research organisations is an effective intervention in many successful EIP transformation projects to establish a baseline at the national level (Fang, Côté and Qin, 2007; Massard, Leuenberger and Dong, 2018; Mirata, 2004). Such intervention can also fill the gap of the difference in the capabilities between the public and the private stakeholders (Farel et al., 2016). Importantly, capabilities in existing IPs are isolated at the firm level with little joint capability based on existing collaborative relationships and no adequate management structure to promote transformation is commonly in place (Zhu et al., 2015; Park et al., 2008). Therefore, an intervention is needed to transform individual firms' capability into the overall capability of EIP through knowledge sharing, for example (Susur et al., 201b).

Coming to the last factor, a stable symbiosis network is a key to the success of the EIP transition (Desrochers, 2001; 2004; Park et al., 2008), and this factor integrates aspects from the previous four factors. The network primarily requires scalability, diversity, and openness to accept new linkages and improve long-term.

Matching based on the input-output processes can help find potential IS linkages and associated platform and information sharing technologies can help firms gauge potentials for such linkages (Chertow, 2000; Xu et al., 2017), although firms with potential for establishing IS linkages may not necessarily perceive each other as prospective partners (Boons and Spekkink, 2012). In network design and optimisation processes, there is an optimal match from the output stream to the input stream, and the optimal result for the materials contained in the network can be obtained after multiple calculations (Côté and Smolenaars, 1997; Yeo et al., 2019). This structured governance approach is usually applied in "top-down" EIP projects, but a firm highly embedded in an IS network may find it costly to break away from the network

fully or partially. This explains why forming a highly cooperative symbiotic network structure is difficult in "bottom-up" projects or regions with more developed technologies (Mathews, Tan and Hu, 2018; Desrochers, 2002; 2004).

Chertow (2007) points out that the process of developing "top-down" EIP projects initially includes discovering immature bilateral or multilateral exchange kernels and then developing them into IS exchanges that fully comply transfer of at least two resources between three different entities. However, there may not necessarily be kernels among firms in the same IP, and such kernels are likelier in regions (Jensen et al., 2011; Sterr and Ott, 2004). The purely commercial operation potential of candidates also needs to be analysed to ensure that the firm is financially viable during the later Adjustment stage (Domenech et al., 2019). Even on a small scale, the lack of overflow in the input-output relationship will reduce the symbiosis network's stability (Taddeo, Simboli and Morgante, 2012). To develop an adaptive network, it is crucial to have redundancy of synergies and industries (Tiejun, 2010; Chopra and Khanna, 2014). Furthermore, regulatory approval processes to allow for the use of by-products at a significant scale may be complex and/or lengthy (van Beers, Bossilkov and Lund, 2009) Overall, this factor is highly complex and there are trade-offs here that interact with the range of factors among several stages of the process.

Synthesised framework

Figure 6 shows the synthesised framework on key stakeholders and their actions in the five stages of EIP transformations. The displayed process describes the most likely progression of a successful project. Note that this framework applies to "bottom-up" and "top-down" projects as *Covering* and *Adjusting* are included.

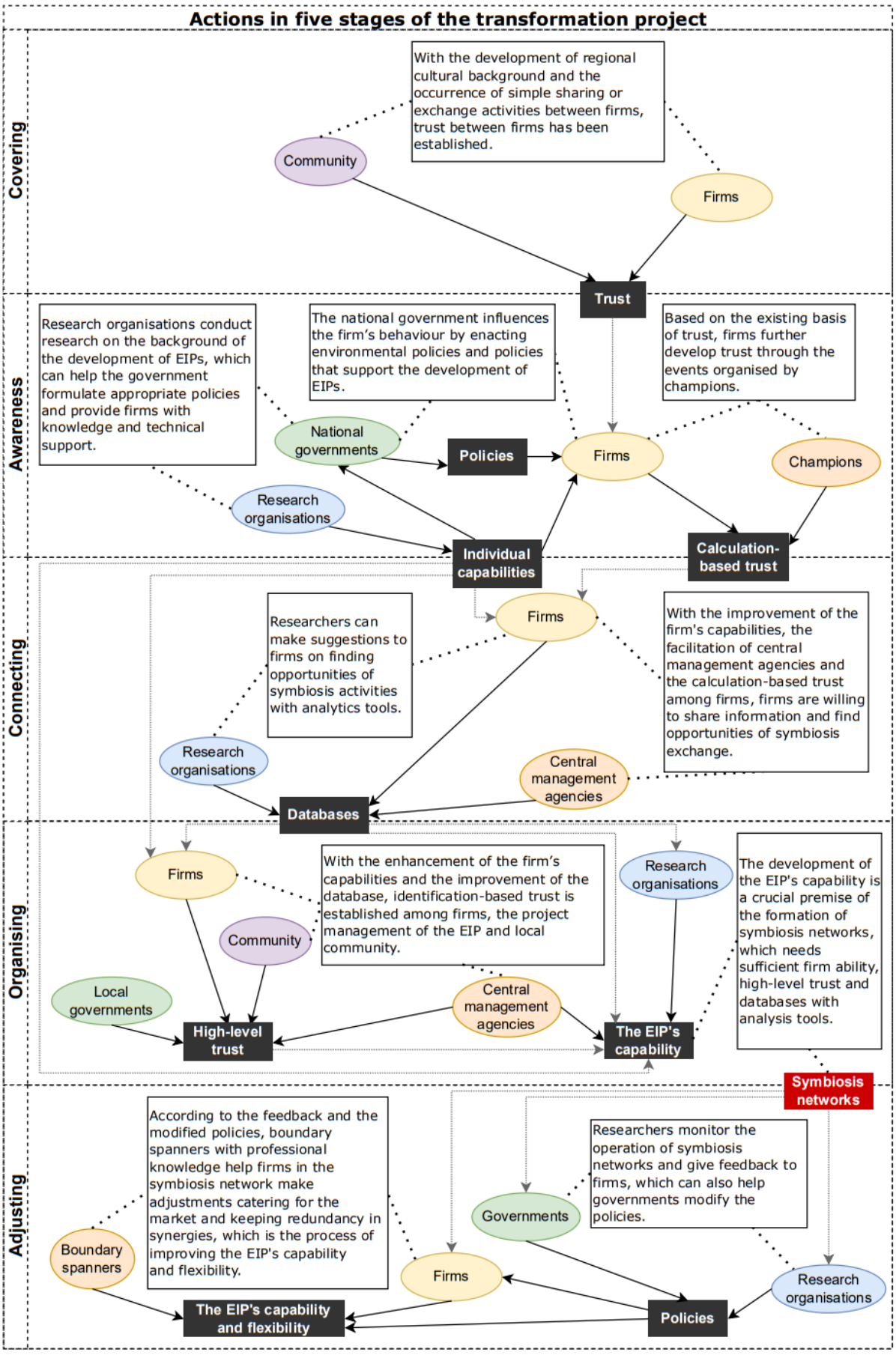


Figure 6: Synthesised EIP transformation framework combining stakeholders and factors (by authors).

5. Discussion and conclusion

This research has reviewed the literature on EIP transformation projects. Our descriptive analysis highlights increasing research interest in EIP transformation as IS initiatives and policies in developing countries especially attempt to modernise existing IPs and unlock concurrent sustainability and profitability. More recent studies illuminate the business and project management side of the transformation. However, as our descriptive analysis of the body of literature on EIP transformation shows, a framework that integrates the wealth of existing knowledge to explain how key stakeholders in EIP transformation projects come together to organise at different points in time is still missing.

Our thematic analysis addresses this gap in the literature by analysing the existing literature in-depth from a process theory perspective to synthesise an EIP transformation framework that includes five stages during which five key stakeholders come together. Their interaction during these stages facilitates the emergence of "bottom-up" and "top-down" EIP transformation, the success of which is further influenced by five factors we identify in the literature. The connections and interactions between these three types of constructs have been analysed and ordered according to the progression of processes in such transformation projects using a process theory perspective.

The five-stage process synthesised in this research draws on process theory (Langley et al., 2013; Pentland, 1999) and should be seen as an attempt at structuring EIP transformation projects, with the rarer "bottom-up" projects more engaged in the initial C*overing* stage and "top-down" projects more engaged in *Adjusting*. These two types of EIP transformations will likely remain relevant as different approaches to economic development prevail in different countries, but the unified framework presented here also shows the similarities and the overarching importance of trust among stakeholders. *Covering* is critical for this development

of trust. When it is absent in "top-down" projects, government and boundary spanners will have to act to compensate in later stages as firms often do not see why they would increase dependency on one another through material exchanges. Research organisations may inform firms and establish a baseline of knowledge and understanding of IS concepts but may not have the power or reach to foster trust effectively. Beyond these stakeholders, firms will also have to trust their own and each other's capabilities and intentions to maintain IS exchange as interdependencies are increased in EIPs. "Bottom-up" projects again have an advantage here because early cooperation and networking are carried over. During *Connecting* and *Organising*, additional systems like databases can help solidify intentions to foster trust in the EIP as a workable and commercially viable proposition. Firms can engage in these stages to drive progress if suitably prepared previously and operating in a regulatory environment made favourable by governmental stakeholders. As linkages are formalised, firms may already be aware that future exchanges will have recalibrated based on other EIP members' needs. This is where a shifting mind-set towards the EIP level should come into play in *Adjustment*.

This study fills several gaps in the EIP transformation literature. First, this study builds a connection between the stakeholder network and the sequence of activities, as well as the influencing factors that enable or hinder EIP transformation at different stages. Previous literature has considered the components of our framework individually; for example, several studies consider some stakeholders in detail, but not all potentially influential ones (e.g., Valentine, 2016) or relationships between stakeholders are not made explicit (e.g., Hewes and Lyons, 2008; Yu, Han and Cui, 2015). Other studies identify and specify influencing factors in-depth but do not specify when or how the relevant stakeholders negotiate them (e.g., Sakr et al., 2011; Susur et al., 2019). This fragmentation of knowledge is expected in a quickly growing body of literature. Our study connects this knowledge and synthesises a detailed framework of EIP transformation. The usefulness of this framework for the literature is

Second, as much work has been done on "top-down" projects where government and boundary spanners are emphasised, firms have often been cast as passively accepting the transformation of existing IPs into EIPs. As such there is a notion that firms are pushed into a transformation (Veiga and Magrini, 2009; Mathews, Tan and Hu, 2018; Taddeo, 2016). However, this study shows that there are cases beyond Kalundborg that pre-empt the intervention of government or boundary spanners to start working in EIPs autonomously, such as Van Beers, Bossilkov and Lund's (2009) study of an Australian EIP. The relationship between the stakeholders can be equal in such cases, although their importance and power may slightly change over time, as shown in different stages.

Third, previous studies mentioned the importance of trust but largely failed to explain the development process of trust in different EIP stages and its interaction with other influencing factors. For example, the trust model established by Ramsheva, Prosman and Wæhrens (2019) explained how boundary spanners could enable trust between firms. Mortensen and Kørnøv (2019) instead focused on the activities in different processes of IS establishment but did not consider the wider stakeholder network necessary to support the business case behind the actual EIP transformation. The synthesised framework in this study, however, shows that as firms in the EIP will have to form both exchange and financial dependencies to enable successful EIP transformation, trust between firms and other stakeholders is crucial, and that boundary spanners may not be able to establish trust by themselves at each stage. The framework developed in this study, therefore, fills in the gaps of Ramsheva, Prosman and Wæhrens (2019) and others by providing an overview of when different stakeholders facilitate trust at different EIP transformation stages

Last, our overview of the existing literature and particularly the contributions and limitations thereof summarised in the Appendix (Table A.1 and A.2) may serve future researchers in their projects on EIP transformation. Several avenues for future research emerge from this overview,

most importantly the need for more studies that consider the dynamics within EIP transformation projects as goals and relationships of relevant stakeholders shift over time – Park, Park and Park's (2016, 2019) studies are examples of this and more such work from a firm-perspective would benefit our literature significantly.

Our main contribution emerges from our summary of the literature and synthesis of the EIP transformation framework, and we invite scholars to test our framework and specify or adjust our propositions. In addition, two future research opportunities emerge from a dearth of knowledge in areas relevant to our framework.

Our process framework assumes that EIPs are transformed from existing IPs. However, there is a lack of description and analysis of the status of existing IPs and relationships between co-located firms before the initiation of an EIP transformation project. It is, therefore, possible that there is an even earlier process to *Covering*. As such, the five stages proposed here are not normative but reflect current knowledge. More research on the early beginnings of EIP transformation projects would help clarify how "bottom-up" projects start at *Covering* or even before; note that even early research on Kalundborg could not pinpoint how decision-makers first set up IS linkages in the first place (Ehrenfeld and Gertler, 1997). In-depth investigations (for example, through ethnographic case studies) of the exploratory contacts between individuals from firms and local communities or governments would be valuable in developing knowledge here. EIP transformation literature has not fully considered the importance of individuals and their motivations, goals, and behaviours. We recommend engaging with these topics, as illustrated in other sustainability research (e.g., Ren et al. 2021).

Adjusting is similarly under-researched. To what extent is this ongoing process of reconfiguration still driven or mediated by government authorities, research organisations, or boundary spanners? How are commercial and environmental viability negotiated as the EIP matures and the park, its stakeholders, and the wider environment changes? Future research

could conduct longitudinal studies on a select group of EIPs to trace their journey along our framework into the *Adjusting* stage in particular, or query a larger amount of EIPs on their reconfiguration organisation and practices through surveys.

Our study is not free of limitations. First, our attempt to offer a succinct overview and synthesis of the literature means that some issues could not be conceptualised in as much detail as possible. For example, we have highlighted the importance of trust at different stages and as facilitated by different stakeholders but could not delve deeper into successful or unsuccessful trust-building mechanisms. Detailed qualitative work to further elaborate our framework would be valuable, for example, what determines the trustworthiness of local government support during the *Organising.* Second, we have applied a quality criterion to our literature search in line, as demonstrated by Aguinis, Ramani and Alabduljader (2018) and others. While we have included further key studies via cross-referencing, our overall focus on business journals commensurate with the focus of our review means that papers in environmental engineering journals were excluded, and the risk of excluding potentially relevant work was also present in previous reviews on EIP topics (e.g., Yeo et al. 2019). Our study thus does not offer detail on the physical infrastructure, technology, and processes underpinning IS exchanges, although papers focusing on their development and use may also have managerial implications for EIP transformation, likely particularly during the *Adjusting* stage. Future work could consider that body of literature in more detail to consider our findings from a socio-technical perspective.

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Appendix

Table A.1: Overview of reviewed articles (by authors).

No	Author (Year)	Title	Type	Location	Main contribution	Limitation
1	Bacudio et al. (2016)	Analysing barriers to implementing industrial symbiosis networks using DEMATEL	Modelling & Case study	Philippines	Evaluates the strength of ten possible barriers to EIP transformation taken from existing literature; "lack of awareness of IS" and four support/funding/trust-related barriers appear most relevant in an EIP case, with technology least important; some connections between barriers are identified	Strategies for addressing these barriers remain general and it is unclear to what extent the barriers are driven by contextual factors of the specific EIP and which stakeholders may influence them
2	Bai et al. (2014)	Insights on the development progress of national demonstration eco-industrial parks in China	Survey	China	Presents the development progress and performance of 33 national demonstration EIPs in China while considering their geographical distribution, region, and industry	The study is largely descriptive account; determinants of progress are not made clear
3	Boons and Spekkink (2012)	Levels of institutional capacity and actor expectations about industrial symbiosis: Evidence from the Dutch stimulation program 1999-2004	Conceptual	Netherlands	Considers that social conditions necessary for IS linkages and hypothesises that institutional capacity makes a firm in an EIP more likely to be perceived by others as a partner for IS linkages; only mobilisation capacity increases this perception	The study does not test whether perceptions resulted in actual IS linkages, firms in the EIPs already had visibility and communication networks with each other and other stakeholders are not fully considered
4	Chen et al. (2017)	Clustering enterprises into eco-industrial parks: Can interfirm alliances help small and medium-sized enterprises?	Survey	China	Validates that interfirm alliances can help SMEs join EIPs, five key influencing factors are identified (policy, market, managerial, financial, and technical) whose importance to firms depends on their size	The temporal aspect of how interfirm alliances may support SMEs at different points in time is neglected
5	Chen, Xu and Zhou (2017)	Regulating the environmental behavior of manufacturing SMEs: Interfirm alliance as a facilitator	Case study	China	Finds that interfirm alliances can help SMEs enter EIPs because they provide external resources to help SMEs adapt to stricter environmental regulation, explore new development paradigms, and help diffuse new paradigms that SMEs have uncovered	The result of this study was derived from a single case study with limited data; the authors propose that further research is needed to verify findings, other stakeholders or temporal aspects not considered
6	Chertow (1999)	The eco-industrial park model reconsidered	Conceptual	/	Identifies a continuum of IS based on their area scope and type of exchanges and affirms "the anchor tenant approach" in promoting the construction of EIPs	The article, including the conceptualisation of "the anchor tenant approach", is compellingly argued but not fully evidenced
7	Chertow (2000)	Industrial symbiosis: Literature and taxonomy	Literature review	/	Provides a taxonomy of five different material exchange types and proposes that three tools may advance EIP development: input-output matching, actors processes and materials budgeting; also suggests that cooperation necessarily develops over time through collaboration and synergies in geographic proximity	This study did not mention how the three methods of promoting the development of IS work together and which stakeholders were necessary for the process of adopting a certain approach
8	Chertow (2007)	"Uncovering" industrial symbiosis	Literature review	/	Reviews historical motivators and means of IS and examines several more recent projects that contain more self-organisation; recommends ways in which IS kernels can be uncovered and grown into larger IS networks	Contextual factors that may allow the development of IS kernels into larger networks or EIPs are largely ignored, and only a few stakeholders are considered for uncovering and fostering kernels
9	Chopra and Khanna (2014)	Understanding resilience in industrial symbiosis networks: Insights	Case study	Denmark	Suggests that an increase in redundancy of synergies and industries in an IS network may axiomatically promote its resilience by favouring flexibility or plasticity	The authors argue that most IS exchanges are based on ad-hoc opportunities (i.e., bottom-up approach) rather than top-down planning, which may not actually

		from network analysis			of the network that provides alternative opportunities for synergies if a node or edge is removed	represent the most common type of EIP; also does not consider how such opportunities are actually seized
10	Costa and Ferrão (2010)	A case study of industrial symbiosis development using a middle-out approach	Case study	Portugal	Concludes that interventions by various stakeholders to influence contextual factors at different levels were critical to foster IS development and provides a five-step "middle-out" process to enable IS development through such interventions	The core idea of a "middle-out" approach is only partially validated using a single case. Interactions between stakeholders are neglected
11	Côté and Cohen-Rosenthal (1998)	Designing eco-industrial parks: A synthesis of some experiences	Literature review	Various	Lists 11 characteristics of EIPs that distinguish them from regular IPs based on existing projects in several initiatives; also suggests a systems approach is needed to understand the physical, chemical, regulatory, economic, and managerial aspects of EIPs	The EIPs mentioned in this study were all in the early stages of development, that as the authors admit, there may be more characteristics as EIPs are planned, designed and operated; also, the existing ones are not ordered or structured according to timing or attributed to relevant stakeholders
12	Côté and Liu (2016)	Strategies for reducing greenhouse gas emissions at an industrial park level: A case study of Debert Air Industrial Park, Nova Scotia	Case study	Canada	Identifies many strategies that can be pursued individually and cooperatively by firms in IPs for preventing, reducing, and mitigating greenhouse gas (GHG) emissions	This study includes a relatively narrow range of actors and underlying success factors of strategies; why firms do or do not pursue the mentioned strategies is largely uncertain
13	Côté and Smolenaars (1997)	Supporting pillars for industrial ecosystems	Case study	Canada	Investigates the diversity needed for EIPs needed to become stable in the long term, which requires three supporting pillars: technical information, economic instruments, and regulations. The study concludes that a stable and resilient industrial ecosystem involving multiple industries and sectors would only exist if all possible niches were filled	This research ignored factors other than resources that may affect the exchange activities of firms; few stakeholders that may influence the three pillars are considered
14	Desrochers (2001)	Cities and industrial symbiosis: Some historical perspectives and policy implications	Conceptual	Various	Argues that although some interfirm recycling linkages will always spontaneously emerge at the local and regional level in any reasonably diversified industrial setting, these will not cover the totality of recycling linkages, nor should they be forced to do so at the expense of interregional linkages	The actual practice of EIP transformation at the level of individual parks is neglected in favour of the legal and economic requirements at the macro level necessary for EIPs and IS exchanges to become generally viable
15	Desrochers (2002)	Regional development and inter-industry recycling linkages: Some historical perspectives	Conceptual	Various	States that IS is a new label given to existing practice and shows using historical examples that similar exchange mechanisms have been ongoing since the 1800s, also argues that the contemporary focus on regional linkages over interregional linkages may be misguided	The extent to which the historical examples (many of which feature inter-regional linkages) actually improve environmental outcomes is uncertain; the stakeholders and their actions for forming either type of linkages are not considered in-depth
16	Desrochers (2004)	Industrial symbiosis: The case for market coordination	Conceptual	UK & Hungary	Argues that calls for more public planning in IS development may not be better than self-organisation as a result of market mechanisms and innovative institutions that can force firms to "internalize their externalities" while leaving them the necessary freedom to develop new and profitable uses for by-products	This research looks at the development of IS from an economic and mechanistic point of view and lacks the discussion of environmental and social factors when discussing policy formulation and firm participation
17	Domenech et al. (2019)	Mapping industrial symbiosis development in Europe - Typologies of networks, characteristics, performance and	Survey	Europe	Illustrates that IS activity produces important environmental, economic and social benefits and contributes to the circularity of the manufacturing sector; also finds that IS exchanges still face a number of obstacles in Europe,	The authors state that the findings mainly reflect IS drivers/obstacles from the perspective of facilitators or coordinators, whereas firms, particularly of self-organising networks, may have different perspectives

		contribution to the circular economy			some of them related to risk and others to the low commercial margins of IS projects and transaction costs	
18	Dong et al. (2018)	Evaluating environmental performance of industrial park development: The dase of Shenyang	Case study	China	Traces changes in the environmental performance of an EIP through a three-stage development structure; emergy sustainability is focused on and renewable emergy ratio identified as a key impact factor	The establishment of the three-stage development model revolved around the network of firms and activities but lacked discussion of other stakeholders or influencing factors
19	Ehrenfeld and Gertler (1997)	Industrial ecology in practice: The evolution of interdependence at Kalundborg	Case study	Denmark	Identifies a very low chance of finding pairs of coexisting positive environmental, technical, and economic factors among more than one or two firms at any one time, and so concludes that Kalundborg's positive development (relying mostly on independent and economically motivated actions by stakeholders) may not be easily replicated elsewhere	Findings from Kalundborg are transferred to some degree to other regulatory and economic contexts, which may be problematic; firm-level issues such as organisational culture are ignored
20	Veiga and Magrini (2009)	Eco-industrial park development in Rio de Janeiro, Brazil: A tool for sustainable development	Case study & Survey	Brazil	Finds that EIP programmes to achieve sustainability in social, economic and environmental aspects can be compromised by changes in political administrations and public agency leadership, particularly as such changes may remove government support for EIP transformation	The EIP programme the study considered was at a very early stage and mostly political and institutional issues are focused on
21	ElMassah (2018a)	Industrial symbiosis within eco-industrial parks: Sustainable development for Borg El-Arab in Egypt	Case study	Egypt	Highlights areas for governmental support and involvement to ensure transformation of EIPs: a strong legal framework, investments and coordinated support; also suggests that new firms might be needed when transforming an existing IP into EIP to close loops	The study's findings are context-specific, although the suggestion that additional firms could provide processes that further enhance by-product exchanges appears transferrable
22	Elmassah (2018b)	Achieving sustainable industrialisation in Egypt: assessment of the potential for EIPs	Case study	Egypt	Examines how EIPs can contribute to sustainable industrialisation enshrined in the sustainable development goals (SDG); finds that several regulatory, institutional, and financial factors impede the success of three prospective EIPs in Egypt and proposes recommendations on how these factors can be overcome	The study's findings mostly relate to policy planning and enforcement, with less attention paid to proactive action by firms or other stakeholders
23	Fan et al. (2017)	Study on eco-efficiency of industrial parks in China based on data envelopment analysis	Modelling	China	Points out that industrial value-added per capita, industrial structure, policy and scale are the most important influencers of eco-efficiency and that an effective mechanism of policymaking needs to be formed to increase eco-efficiency according to different situations in different EIPs	The indices used in the eco-efficiency evaluation did not cover all the sustainability dimensions of IPs, some of which were crucial to making the indicator more useful; little information on how stakeholders may work towards high performance
24	Fang, Côté and Qin (2007)	Industrial sustainability in China: Practice and prospects for eco-industrial development	Case study	China	Concludes that, at the time, China's IE efforts and EIPs were in their infancy, also suggests that EIPs and IE initiatives has not yet become a core pillar of China's industrial policy; awareness of eco-industrial development possibilities and profit potentials are key, and continued government support is needed	The study struggles to specify who owns and when the proposed success factors become relevant; firms, government, and academic institutions are mentioned but only partially connected with the named success factors
25	Farel et al. (2016)	Sustainable manufacturing through creation and governance of eco-industrial parks	Case Study	Various	Traces the relationship between origin and context of EIP initiatives to development and management; emphasises the importance of the participation of public authority to foster EIP development when environmental concerns are involved, and the influence of the	This research ignored the process of how the aims of different actors engaged in the EIP projects combined to get the common goal

					social context and the presence of a certain gap of cohabitation of the two extreme systems, i.e., public and private	
26	Fraccascia and Yazan (2018)	The role of online information-sharing platforms on the performance of industrial symbiosis networks	Modelling	/	Shows that online platforms that share demand/supply information of firms can foster IS networks; proposes that some information that is often considered sensitive may not actually be sensitive but still important for IS networks	Two hypothetical cases are simulated; the authors admit that decision-making rules may be different in different sectors or locations; only firms are considered in the model
27	von Malmborg (2004)	Networking for knowledge transfer: Towards an understanding of local authority roles in regional industrial ecosystem management	Literature review	/	Claims that local government authorities can play at least two roles in the process of knowledge transfer between firms (knowledge banks or knowledge brokers), but also highlights that such authorities often act as an institutional anchor tenant to projects	This research focuses on local government authorities and largely disregards the complexity of EIP transformation over time with multiple relevant stakeholders
28	Gibbs (2003)	Trust and networking in inter-firm relations: The case of eco-industrial development	Literature review	/	Argues that a more nuanced approach is needed for conceptualising exchanges in EIPs, draws upon work in economic geography and regional economics to explain that trust, networking and untraded interdependencies between firms in an EIP need to be deliberately fostered	The author sees the disregard for the temporal dimension of EIP transformation as a limitation in the existing literature
29	Gibbs, Deutz and Proctor (2005)	Industrial ecology and eco-industrial development: A potential paradigm for local and regional development?	Survey	USA & Europe	Claims that there is a major disconnect between the theory and practice of IE as there are few successful cases that implement significant exchanges like those present in Kalundborg	The importance of inter-firm relationships and public sector involvement in promoting the development of exchanges are mentioned, but there is no discussion on how the development of trust and other factors may affect exchanges
30	Hashimoto et al. (2010)	Realizing CO2 emission reduction through industrial symbiosis: A cement production case study for Kawasaki	Case study & Survey	Japan	Provides a basic framework to identify how reduced CO2 emissions can be achieved by IS practices in a large EIP; presents recommendations for further improvements that takes local economy and legal factors into account	This study only focuses on CO2 emissions and bases assumptions on a single year; the implementation of the further changes to the EIP by different actors are considered at a very general level and not clearly attributable to stakeholders or timings
31	Hewes and Lyons (2008)	The humanistic side of eco-industrial parks: Champions and the role of trust	Case study	USA & Europe	Highlights the significance of humanistic connections, specifically the role of EIP champions, and shows that the development of social relationships (not just technological connections) are necessary to create an EIP	This study pays attention to the development of trust in social relationships but does not analyse its characteristics at each development stage of EIPs
32	Hwang, Jeong and Ban (2016)	Causal relationship of eco-industrial park development factors: A structural equation analysis	Survey	South Korea	Identifies the impact structure of EIP development strategies (factors) on EIP development to establish reasonable strategies for sound and sustainable EIP development	The authors admit that the findings are limited to the South Korean context and that further empirical data is needed; strategies are relatively general
33	Jensen et al. (2011)	Quantifying "geographic proximity": Experiences from the United Kingdom's national industrial symbiosis programme	Survey	UK	Examines the role of geographic proximity between members of IS networks in the UK, finds that material exchanges travel a median of 20.4 miles and thus shows that exchanges can be viable at a distance	The authors admit that the distance travelled may differ in other countries; the findings do not fully connect to purposefully developed EIPs
34	Korhonen and Snäkin (2005)	Analysing the evolution of industrial ecosystems: Concepts and application	Case study	Finland	Argues that diversity and cascading and cyclical flows (termed "roundput") in the case of industrial ecosystems may be important for sustainability and observes a relation between the two factors: diversity enhances roundput	The authors admit that the analysis rests on relatively little data, and the argument is mainly conceptual; stakeholders or factors underpinning the achievement of roundput are not considered
35	Le Tellier et al. (2019)	Towards sustainable business parks: A	Literature review	France & Canada	Proposes the concept of a mixed-use ecopark (MUE) as a subtype/mix of EIPs and sustainable	This study largely ignores the role that firms may play in such parks and the interactions they may

		literature review and a systemic model	& Case study		urban planning approaches; creates a baseline for the definition and evaluation of MUEs' performance	engage in with other potential stakeholders
36	Massard, Leuenberger and Dong (2018)	Standards requirements and a roadmap for developing eco-industrial parks in Vietnam	Case study	Vietnam	Develops a bottom-up participative process of EIP transformation in developing economies to overcome resource issues and gauge actor interest; a standardisation scheme is developed to compare outcomes and variability in criteria and indicators to ascertain at which point an EIP is different from an IP	The study focuses mainly on defining EIPs and locating them in the Vietnamese policy space; implications for firms interested in EIP transformation are limited to recommendations aligned with the developed process
37	Mathews, Tan and Hu (2018)	Moving to a circular economy in China: Transforming industrial parks into eco-industrial parks	Case study	China	Identified various critical "bottlenecks" from a systemic perspective in the evolution of industrial parks moving from linear production systems to CE systems, with network governance most critical to enabling firms to find common cause in EIPs	This study lacks the comparison and the comprehensive discussion of different stages, stakeholders and activities in the transformation process of selected EIPs
38	Mirata (2004)	Experiences from early stages of a national industrial symbiosis programme in the UK: Determinants and coordination challenges	Case study	UK	Examines influencing factors of an IS network and finds that nature of firms' operations, regional industrial histories, peer pressure among firms, and the positioning and awareness-raising strategies and recruitment of a not-for-profit coordinating body are most important	This study emphasises the effects of some factors on the development of IS networks but does not discuss the processes behind these effects and possible solutions at the level of individual EIPs
39	Mortensen and Kørnøv (2019)	Critical factors for industrial symbiosis emergence process	Literature review	/	Identifies a three-part conceptual model of the IS emergence process, including five critical factors: contextual conditions, actors, roles, characteristics, and activities	The conceptual model does not consider how actors' interactions change at different points in time as the model is not organised chronologically, two parts of the model are relatively undefined
40	Park and Won (2007)	Ulsan eco-industrial park: Challenges and opportunities	Case study	South Korea	Concludes that the challenges in the Ulsan EIP project are primarily insufficient awareness of EIP among firms and to bring the present environment regulations and standards in line with goals of the Ulsan EIP	The case analysed in this study was still in the early stages of transformation, and there was a lack of discussion of different stakeholders and their relationships to each other because of this
41	Park et al. (2008)	Strategies for sustainable development of industrial park in Ulsan, South Korea-From spontaneous evolution to systematic expansion of industrial symbiosis	Case study	South Korea	Identifies that system analysis including industrial metabolism, input-output analysis, environmental evaluation and flexibility analysis must be conducted for potential IS networking; the Ulsan EIP project must be associated with the regional strategic environmental technologies and businesses	The objects studied in this article were in the early stage of developing EIP as part of a government-initiated pilot project; most of the study describes future plans and lacks data to support more instructive conclusions
42	Park, Park and Park (2016)	A review of the national eco-industrial park development program in Korea: Progress and achievements in the first phase, 2005–2010	Survey	South Korea	Attributes the achievement of the first five years of a government EIP programme to several success and limiting factors; suggests that an institutional system that combines top-down and bottom-up approaches and the mediating role of regional EIP centres are responsible for achievements so far	Findings are context-specific; more importantly, it is unclear how the identified success and limiting factors relate to the involved stakeholders
43	Park, Park and Park (2019)	Scaling-up of industrial symbiosis in the Korean national eco-industrial park program: Examining its evolution over the 10 years between 2005–2014	Survey	South Korea	Introduces three key scaling-up strategies adopted in the second phase of the Korean EIP programme and examines the way that IS evolved in the second phase in terms of the number of operating projects and participating firms, etc.; also suggests that regional EIP centres acted as facilitators	This study paid much attention to the performance results of the EIP project but did not conduct an in-depth exploration of the processes and stakeholders that caused such results; the roles/activities of regional EIP centres are only partially explained
44	Pellenbarg (2002)	Sustainable business sites in the Netherlands: A survey of policies and experiences	Case study & Survey	Netherlands	Reviews Dutch progress on EIP with a survey and several short case studies; main contributions are the identification of problems of these EIPs and that a time perspective	The study considers the changes in EIPs over time, but lacks more detailed research on the relationship between different

					where the ultimate goal is continuity of the firm and its environment, not sustainability in purely ecological terms may better be suited for EIP development	stakeholders involved in EIP transformation
45	Ramsheva, Prosman and Wæhrens (2019)	Dare to make investments in industrial symbiosis? A conceptual framework and research agenda for developing trust	Literature review	/	Provides a trust framework including the role of boundary-spanning agents, the application of different trust developing strategies, and different trust types	Other stakeholders and their activities/influence on the actions of boundary-spanning agents and their effectiveness of the strategies in EIP transformation are considered to a very limited degree
46	Sakr et al. (2011)	Critical success and limiting factors for eco-industrial parks: Global trends and Egyptian context	Case study	Egypt, Various	Synthesises success and limiting factors of EIPs and arranges them into six categories: the creation of symbiotic relationships, information sharing and awareness, financial benefits, organisational structure, and legal and regulatory frameworks	The study treats EIP transformation projects as a "black box"; when distinct success and limiting factors are relevant and how involved actors can negotiate them is not clear
47	Sterr and Ott (2004)	The industrial region as a promising unit for eco-industrial development—reflections, practical experience and establishment of innovative instruments to support industrial ecology	Case study	Germany	Finds that EIPs (focused on local exchanges) may not be as powerful as industrial regions with a multitude of existing waste producers and recyclers for IS; such regions are proposed to develop through comprehensive information transparency, and mutual trust among the industrial actors and the willingness to cooperate	The focus on regions and, as such, the perspective of individual actors was considered less. Also, the relationship between EIPs and regions was unclear as the two were treated as almost mutually exclusive.
48	Susur et al. (2019)	Unfolding eco-industrial parks through niche experimentation: Insights from three Italian cases	Case study	Italy	Develops a framework based on the strategic niche management perspective that conceptualises EIP transformation as niche experimentation journeys of existing brownfield industrial parks under mediating regional and national contexts	The authors state that as the case studies were conducted retrospectively, recall bias may be present, and no direct observation was possible; the framework focuses on the social aspects while treating the organisational aspects as a "black box"
49	Susur, Hidalgo and Chiaroni (2019)	The emergence of regional industrial ecosystem niches: A conceptual framework and a case study	Case study	Spain	Uses IE and strategic niche management literature to develop a conceptual framework that shows how local IS experiments can result in regional industrial ecosystems and thus achieve a sustainability transition; main factors of the framework are related to social activities or actor coordination	Local experiments sometimes are or aspire to be EIPs, but the relationship between the two levels of the framework and EIPs is generally uneasy and not clarified; the scope of the framework for EIP is thus unknown
50	Taddeo (2016)	Local industrial systems towards the eco-industrial parks: The model of the ecologically equipped industrial areas	Survey	Italy	Introduces Ecologically Equipped Industrial Areas (EEIA) and argues how these areas can be used to transform IPs into EIPs; the main potentials of EEIAs are centralised infrastructure management, shared services, and the administrative simplifications for the involved firms, while limitations are long time investments, regulatory limits to exchanges, and inflexibility of top-down approaches	While the potential and limitations of the EEA are convincingly argued, the authors note that after 20 years of the EEIA policy, there are no operating EIPs in Italy, meaning that the relationship between potentials and limitations is uneasy; also, either factor is not attributed to specific stakeholders
51	Taddeo, Simboli and Morgante (2012)	Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site	Case study	Italy	Reveals that existing IPs may have the potential for EIP transformation because of several success factors, but that other factors, primarily local community opposition, may prevent or inhibit such transformation	The study looks at the hypothetical potential of a completed EIP transformation in one particular existing IP; also, there is limited regard for temporal aspects of the transformation process
52	Tiejun (2010)	Two quantitative indices for the planning and evaluation of eco-industrial parks	Modelling & Case study	China	Defines two interrelated and inseparable indicators relevant EIPs: eco-connectance and by-product and waste recycling rate; argues that through these indicators, better EIPs can be developed, and assessment may be more aligned with EIP goals	The indicators are illustrated using cases, but the study does not consider the influence of organisational forms, context differences, etc. on the recommendations that are made based on the indicators

53	Valentine (2016)	Kalundborg Symbiosis: Fostering progressive innovation in environmental networks	Case study	Denmark	Presents four core drivers for promoting progressive innovation through EIP cooperation: an environmental mind-set among actors, opportunities to explore potential improvements, mutually beneficial initiatives, and the existence of dominant needs that actors can search solutions for	The focus on a particular EIP makes transferring the findings to other contexts difficult; few relevant stakeholders are considered, and how these engage with the drivers over time
54	Van Beers, Bossilkov and Lund (2009)	Development of large scale reuses of inorganic by-products in Australia: The case study of Kwinana, Western Australia	Case study	Australia	Argues that there is no "one-size-fits-all" approach to promote the development of inorganic by-product synergies, which is related to the drivers, barriers and triggers falling into nine broad categories: regulation, economics, community, technology, transportation, confidential and commercial issues, risk and liabilities, industry focus and priorities, and region-specific issues	This study does not consider that different stakeholders may own or cause the listed drivers, barriers and triggers, also does not consider the progression of time in the evolution of relationships
55	Xu et al. (2017)	3Es-based optimization simulation approach to support the development of an eco-industrial park with planning towards sustainability: A case study in Wuhu, China	Modelling & Case study	China	Assesses the impacts of different EIP development strategies and suggests an optimal development strategy based on several scenarios for the Wuhu EIP in China; the main contribution is in the development of the decision-making model, which integrates the dynamic model of the Environment-Economic-Energy (3Es) system with an input-output model	The authors mention some limitations of the developed model; the recommendations based on the model are only to a limited degree actionable from the perspective of a particular EIP and few stakeholders/activities are reflected in the model
56	Yeo et al. (2019)	Tools for promoting industrial symbiosis: A systematic review	Literature review	/	Provides a framework of the tools (or activities facilitated by software or information systems) and their roles supporting the overall process of enabling IS between firms	The authors mention that the SLR methodology may have excluded some relevant papers; also, not all relevant stakeholders and factors involved in the decision to implement and use the reviewed tools are considered
57	Yu, Dijkema and de Jong (2015)	What makes eco-transformation of industrial parks take off in China?	Case study	China	Shows how policy instruments enable and facilitate EIP transformation in China; finds that at a low level of EIP development, a planned (top-down) is best and that later a facilitated (bottom-up) model can engage firms better, suggests combining both approaches for meeting long-term eco-transformation goals	The authors admit that the data set for evaluating the EIP performance of the two chosen EIPs was relatively small, and the timeline was quite limited (from 2008 to 2011); a longer timeline may have strengthened or altered findings; the combined model is not fully conceptualised
58	Yu, Han and Cui (2015)	Evolution of industrial symbiosis in an eco-industrial park in China	Case study	China	Elucidates how an economic and technology development area (large scale EIP) evolved to a complex IS network over two decades and summarises unique characteristics of IS growth in a developing country from the perspective of firms and government with economic benefit as the primary motivator	An inside view of the firm perspective is lacking; it is not clear how government policy influenced firm activities as the interaction between the two main proposed stakeholders is not considered
59	Yu, de Jong and Dijkema (2014)	Process analysis of eco-industrial park development – the case of Tianjin, China	Case study	China	Presents a process analysis approach that enables the building of a structured database of activities in a particular EIP to analyse its eco-transformation, finds that the EIP was initially planned top-down but then evolves top-down and bottom-up as firms gained more initiative and responsibility through trust and relationship building	Some of the study's findings are not explicitly supported by the data; the triggers for changes are not explicit and the authors admit that the findings may be constrained to the particular policy environment of the chosen EIP and/or China
60	Zhang et al. (2010)	Eco-industrial parks: National pilot practices in China	Survey	China	Summarises the problems encountered thus far in the implementation of the Chinese national pilot EIP programme and provides brief suggestions on the	Problems and suggestions are mostly pitched at the level of national policy and governmental organisation; there are only limited implications for EIP transformation on the ground

					future development of EIPs and the programme itself	
61	Zhu et al. (2015)	Barriers to promoting eco-industrial parks development in China: Perspectives from senior officials at national industrial parks	Survey	China	Provides advice on which governmental policies can promote EIP development, especially relevant to technology innovation and capacity building	The transferability of the insight is questionable; there may be some social desirability bias as few of the senior officials at EIPs encounter significant barriers to EIP development

Table A.2: Overview of how influencing factors develop in the five steps of the EIP transformation process; empty cells denote scarcity of existing knowledge (by authors).

		Policy	**Databases**	**Trust**	**Capability**	**Symbiosis networks**
Covering	Requirements			Calculation-based trust is needed, which makes firms assume that cooperation will have a financial payoff	Leading firms have advanced technology, and knowledge gaps between involved firms do not affect their integration	
	Problems			When cost-saving potentials are low, cooperation stagnates	Low capabilities to solve technological or environmental protection challenges persist	
	Solutions			Short-term commitments can foster calculation-based trust and illustrate that financial payoffs are temporally closer than assumed		
Awareness	Requirements	National governments need to pass appropriate policies that can make firms aware of the necessity to change	Databases that include information on previous success cases or overviews of possible linkages in a localised context are explored		Firms need to have specific knowledge and technical capabilities to recognise the long-term benefits and market competitiveness brought about by cooperation	
	Problems	Strict policies restrict firms from obtaining official permits	Particularly SMEs have limited access to and awareness of such databases		Particularly SMEs have limited IS knowledge and lack technology, which prevents them from being aware of potential benefits	
	Solutions	Researchers and local governments should be involved in formulating policies in line with the regional context	Interfirm alliances can function as an external knowledge distributor		The national government directly provides financial support to research institutions or local governments to disseminate IS knowledge and provide technical support to firms	
Connecting	Requirements	To meet national policies, local governments put forward specific regulations on the implementation of EIP projects	Such databases can illustrate the potential of IS linkages in EIPs and motivate firms to connect with the database	Calculation-based trust and knowledge-based trust are required for firms to share information and cooperate	Enhance firms' capabilities through training activities to enable exchange activities	Local governments and the project management centre need to reasonably control the scale of the EIP and the firms included in EIP

	Problems	Strict policies may prohibit some exchanges in the park or necessitate others that are not necessarily financially viable	Firms may be unwilling to share confidential data about their resource flow and production technology	Different firms have different needs for EIP projects	Local governments may lack technical and management capabilities, so it is hard for them to take responsibility for conducting research and providing support	Even in the planned EIP project, the pre-existing exchange activities are required for the IS network to be successfully established
	Solutions	Local governments could set overall regional goals and encourage adjustment and innovation activities among firms	With the help of public data analysis tools, researchers can explore industry-level collaboration opportunities; trust-building can also induce firms to overcome reluctance on data-sharing	Boundary spanners organise formal and informal activities to help firms build relationships and actively respond to and align their needs	Developing countries can cooperate with experienced developed countries to build EIPs; National research organisations can also provide technology and knowledge support	Researchers and the project management centre should conduct sufficient research before choosing a specific location for developing the EIP and plan the scope of symbiosis activities while determining the firms to be included
Organising	Requirements	Incentive policies need to enable firms to obtain predictable financial benefits	Feedback platform is needed for firms to share information on resource flow and gather knowledge	Identification-based trust is required to integrate expectations of various actors into a collective target	Transform individual firms' capabilities into the overall ability of the EIP	The IS network needs to maintain a certain degree of openness to accommodate new IS linkages and actors
	Problems	The initial investment and risk taken exceed the obtainable benefits	Firms cannot discover potential symbiosis opportunities based on gathered data and experiences in other regions or countries	There is a lack of tools to build a high level of trust and balance out the risks of commitment to the project	There is a lack of inter-firm collaboration and an adequate management structure inside the park	While openness develops with trust, participating firms focus on solving problems, which makes the IS network lack innovation capabilities
	Solutions	The government undertakes the initial infrastructure construction and introduces strict market supervision policies to ensure the interests of legal enterprises	Through data analysis tools, researchers can make suggestions on IS opportunities to the firm and the project management centre	Sophisticated management procedures and engagement, likely resource-intensive	Researchers and the project management centre can facilitate joint development of technology, linkages between firms, and disseminate relevant knowledge	Regional IS networks are being explored; many developed countries are no longer limited to establishing closed-loop symbiosis networks in the EIP
Adjusting	Requirements	Policies may need to be continuously revised as the EIP project develops to ensure viability in a changing environment	Close monitoring of IS activities and timely feedback through the platform by researchers or the firms themselves can help fine-tune exchanges			
	Problems					
	Solutions					