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Public actors and their diverse roles in eco-industrial parks: A multiple-case study

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ABSTRACT

The roles of public actors in promoting the industrial circular economy is uncharted, despite sustainable actions often resulting from collaboration between these actors and private actors. This study therefore illuminated (1) what roles public actors take on in the operation of an eco-industrial park (EIP) and (2) how these roles occur within the actor structure of an EIP? Correspondingly, the research conducted two qualitative case studies on EIPs where public entities are essential actors and analyzed these public spaces via the qualitative content analysis of primary and secondary data. Study 1 extensively analyzed 20 EIP cases around the world. The analysis uncovered six roles played by public actors in EIPs: operator, organizer, financer, supporter, policymaker, and regulator. Study 2 involved a longitudinal exploration of four national EIP cases, an examination of identified roles, and an ecosystem visualization mapping of what positions public actors can assume in an EIP. The research contributes to the literature primarily through the identification of roles, which show how public actor involvement in EIPs can be multifaceted and crucial in successfully operating an EIP. The research also offers new insights and a model of public actor roles in EIPs, serving as a tool for these actors to self-reflect and understand the functions that they can serve in aiming for sustainable EIP operations.

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1. Introduction

Both industries and societies need to overcome the unsustainability of the linear economy model (Ghisellini et al., 2016) and pursue sustainable development. In the circular economy (CE) model, value creation, by its nature, often requires collaboration between the public sector and private business systems (see, e.g., Isaksson and Heikkinen, 2018). CE development is fostered through the creation of eco-industrial parks (EIPs), where "organizations are concentrated on the basis of the possibilities to reuse resources among them in a circular way – to improve competitive advantage" (Ruggieri et al., 2016). By far, the interpretation of CEs in EIPs and, more generally, in industrial ecology research has strongly been biased toward companies and industries (Korhonen et al., 2018), but recent studies have acknowledged the roles of public actors in EIP operations. These particularly include examinations of public regulations and guidelines designed for and applicable to EIPs at the national and regional levels (e.g., Geng et al. (2009) and Daddi et al. (2016), respectively). Although public actors now play more diverse roles in industrial ecosystems (see Uusikartano et al., 2020), most industrial ecology studies have disregarded the roles of governments and public authorities in enhancing or inhibiting industrial ecosystem development (Von Malmborg, 2004). In other words, industrial ecology research recognizes public actors as serving meaningful functions in EIPs without considering the practical manifestations of these roles in a detailed and structured manner.

Previous studies concentrated on the public actor *role* as "a function or part performed especially in a particular operation or process," whereas the current research treated the term as referring to "a character assigned or assumed" (see Merriam-Webster, 2020). I.e., this study was aimed at discovering how the already acknowledged presence of public actors in EIPs manifests and is characterized in practice. Public actors significantly contribute to

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facilitating the development of regional industrial ecosystems (Von Malmborg, 2004), such as EIPs. Most EIPs are developed as part of local economic development strategies, and the level of public involvement in this development can be very high (Gibbs and Deutz, 2007). Many researchers stressed the importance of public actors in supporting EIP development and related environmental aspects, such as motivating the use of waste materials through various means, including policymaking, legislation, financial incentivization, information sharing, infrastructural development, and education (Lehtoranta et al., 2011). In Tuscany, Italy, for example, local public actors have created a voluntary environmental certification scheme for EIPs which, together with strong involvement from public actors, seems to be the only efficient way of engaging different actors in collaboration (Daddi et al., 2016). In Sweden, three main types of public–private partnerships for regional sustainable development, all initiated by public actors, have been recognized (Von Malmborg, 2004). Similarly in China, a national standard for promoting EIPs and industrial symbiosis has been formulated (Geng et al., 2009). As the actions of public actors can be concentrated in EIPs at the local, regional, or national level, entities that represent these actors also vary. The present study defined a public actor as a public organization that is subject to political rather than market control and whose objectives, structures, and processes are often set by legislation or bureaucratic agencies (Parker and Bradley, 2000). Public actors include various entities involved in EIP studies, namely, state legislatures (Veleva et al., 2015); local municipalities (Liwarska-Bizukojc et al., 2009); local (Yu et al., 2015b), national (Van Berkel et al., 2009), or state governments (Elabras Veiga and Magrini, 2009); and national environmental agencies (Paquin and Howard-Grenville, 2013).

Variations are also seen in approaches to public actor involvement, which can vary between contexts owing to distinct social environments and structures across the world (see, e.g., McDowall et al., 2017). By far, however, the means recognized or suggested for public actors to promote EIPs seem to be divided largely into financial and regulative approaches, which have been applied in many countries in Europe, North America, and Asia (Daddi et al., 2016). Related economic instruments include financial subsidies (Daddi et al., 2016) and tax reliefs (Ruggieri et al., 2016). In their study on 16 US and European EIPs, Gibbs and Deutz (2007) found 15 out of 16 cases to be either fully or partly financed through public funding. Public funding is also the main source of financial support for the Italian EIP cases examined by (Tessitore et al., 2015), with public financing relevant or very relevant to 63% of the cases. In addition to financial support, regulatory frameworks have been identified as an important factor for public involvement in EIPs; such initiatives encompass the imposition of limits with respect to the treatment of certain waste streams (Ruggieri et al., 2016).

Public actors may be instrumental to supporting the development and management of regional industrial ecosystems (Von Malmborg, 2004). For this purpose, public actors can deploy an integrated set of policy instruments aimed at actively steering current markets toward sustainability through increased collaboration between companies (Costa et al., 2010). Although several regulative and financial means have been avenues through which the public actor involves itself in EIPs, the functions of public actors are changing from solely regulatory supervisory roles and control over industries to the stimulation of inter-organizational collaboration for environmental management (Von Malmborg, 2004). This shift calls for a detailed examination of public actors' roles in EIPs and their effects on these institutions (e.g., Lehtoranta et al., 2011; Fratini et al., 2019). Some vague interpretations of the roles that public actors play in EIPs have been put forward. According to Gibbs and Deutz (2007), public actors can serve as enablers that help companies create opportunities and appropriate conditions for inter-organizational collaboration through policy intervention. In this sense, public actors are coordinators of EIPs (see Tessitore et al., 2015). Von Malmborg (2004) suggested that public actors are network brokers and managers as well as "knowledge banks" or "knowledge brokers" in regard to information flows within local industrial ecosystems. In addition to operative and supportive roles of public actors, Uusikartano et al. (2020) recognized also financial, regulative and political means for public actors in industrial CE ecosystems that closely relate to EIPs. To summarize the identified research gap, scientific discussion has concentrated on what public actors should do to promote EIPs rather than how they should promote EIPs or how they should fulfill their significant role in practice.

Overall, industrial ecology research has extensively studied CE applications, but less attention has been paid to the implications of cooperation among different business organizations (Ruggieri et al., 2016). The same seems to apply with respect to the roles taken on by public actors in EIPs, as knowledge of these changing functions in relation to industry for the development and management of industrial ecology at the regional level is lacking (Von Malmborg, 2004). To fill this void, the present work inquired into the forms of involvement that public actors pursue in EIPs and how these roles occur within the actor structures of these parks. The focus is on EIPs as entities that have been referred to as a requirement for CE implementation on a meso level (Ghisellini et al., 2016), a strategy for developing and establishing CEs (Ruggieri et al., 2016), and a basic CE model (Zeng et al., 2017). Public actors have been deemed active agents in the development of EIPs (Von Malmborg, 2004). Importantly, this study regarded EIPs as constituted by both collocated actors and a wider spatial scale of "local-regional industrial ecosystem," consistent with the idea of Gibbs and Deutz (2007). An expansive and comparable global dataset was available for scrutiny from the perspective of public actor involvement and with respect to their effects on EIPs. As previously indicated, the purpose of this study was to comprehensively explore how public involvement in EIPs manifests in practice, that is, what roles are taken by public actors as a means through which to influence EIPs and how these roles occur. Accordingly, two research questions were pursued:

RQ1. Through what kind of practical manifestations—i.e., roles—does public actor involvement in EIPs occur?

Previous EIP studies recognized some roles that public actors play in EIPs in a conceptual and superficial manner (e.g., Lehtoranta et al., 2011; Yu et al., 2015a), but the present research is distinguished from these endeavors in that it specified the variety of practical manifestations of these roles and the manner by which they occur in practical contexts. Here, roles refer to different sets of practices as well as the ways by which actors influence an EIP (e.g., legislation, financial instruments, and formal agreements or organizational structures of EIPs or regulations guiding park operations).

RQ2 How do the roles occur within the actor structure of an EIP?

Roles represent different ways for public actors to involve themselves in EIPs. Because these actors are represented by various entities, a relevant task is to probe into the kind of public actors engaged with EIPs and how they are embedded in the structures of the parks. Although earlier studies depicted the different mechanisms and instruments through which public actors promote EIPs (e.g., Lehtoranta et al., 2011; Yu et al., 2015a, 2015c), they disregarded how public actors are positioned within the structures of EIPs. No knowledge or illustrations of EIP ecosystem structures and governance have been derived or provided (e.g., Parida and Wincent, 2019), despite the fact that a deeper understanding of the organizational landscape characterizing EIPs enables public

actors to better organize public support and fruitful public–private interactions within these institutions.

The current work discovered new insights and details on public contribution and its significance in fostering EIPs in a certain territory in two phases. First, an extensive multiple-case study anchored in secondary data on 20 EIP cases around the world was conducted (Study 1) to uncover the roles that public actors play in EIPs (RQ1). Second, a focused and longitudinal multiple-case study on four Finnish EIP cases (Study 2) was carried out to analyze the identified roles and their co-occurrence within an EIP structure (RQ2). The theoretical contribution is new knowledge about how public actors' roles manifest in practice in EIPs, with the roles serving as a practical model for public actors to self-reflect on available means through which they can promote CEs. The study also provides a visual ecosystem map and a tool that render different public actor entities, their positions and inter-relations, and their ways of involvement in EIPs visible.

The rest of the paper is organized as follows. Section 2 provides a theoretical background on public actor involvement in EIPs. Section 3 describes the research methods used in Studies 1 and 2, and Section 3 discusses the results of the studies. Section 5 presents the theoretical and practical contributions of the research as well as its limitations and avenues for future research.

2. Recognized roles of public actors in eco-industrial parks

Current industrial ecology research acknowledges the significant roles that public actors play in EIPs, especially in their development. Many authors have emphasized the need for public policies, EIP initiatives, environmental legislation, and economic instruments intended to help companies create functioning EIPs (Ghisellini et al., 2016). A public actor is a support system that can advance (Korhonen, 2001) or even shape (Zeng et al., 2017) an institutional environment to support sustainable actions. Publicly supported EIPs implement sustainable practices more frequently than parks with limited public support (Bellantuono et al., 2017). This difference is attributed to companies engaging with EIPs mainly to gain economic benefits (Ghisellini et al., 2016) and the considerable promotion of collaborative arrangements possible via public support (Lehtoranta et al., 2011). Lehtoranta et al. (2011) reported that public environmental legislation and other policy measures reduce emissions in an industrial complex. Public actor involvement in EIPs has been distinctively prominent in Asia (Lehtoranta et al., 2011), where such engagement happens through national EIP strategies, industrial policies for EIP promotion, and eco-friendly industrial structures (see Chiu and Yong, 2004). Especially in China, EIP planning, organization, and funding highly depend on the government (Mathews and Tan, 2011). For instance, at the beginning of the project on the Chinese EIP Rizhao Economic and Technology Development Area (REDA), 28 out of 31 circular actions took place under the guidance of public administration in one way or another (Yu et al., 2015c).

An appropriate combination of public means and guidance as well as business-oriented actions can advance the transformation of industrial parks into EIPs (Yu et al., 2015a). The role of public actors in this respect is to shape the institutional environment in a way that advances sustainable actions (Zeng et al., 2017). Such shaping can be coursed primarily through legislative and economic means, but ideas regarding coordinating and policy instruments have also been put forward (a kind of categorization mentioned by Yu et al. (2015c), Ruggieri et al. (2016), and Daddi et al. (2016)). It can also proceed through research-based suggestions, namely, legislative, economic, coordinating, and policy-oriented means. Legislative means encourage industries to collaborate, for example, through land-use or waste regulation (Lehtoranta et al., 2011) or the removal of regulatory barriers to the safe reuse of by-products (Desrochers, 2004). Economic means motivate companies to collaborate on a voluntary basis (e.g., funding for the development of sustainable actions) or a normative basis (e.g., tax reliefs for sustainable actions) (Ruggieri et al., 2016). Policy-related means are policy interventions that attract or direct industries toward more sustainable actions and include rewards such as material, resource, or energy reuse (Chertow and Lombardi, 2005). Finally, coordinating means relate to public actors enabling and supporting avenues for inter-organizational collaboration; an example are periodic roundtables wherein companies are encouraged to exchange views and experiences (Taddeo et al., 2012).

As mentioned earlier, extensive research has been devoted to how public actors promote EIPs, but studies on how these means are manifested in practice are scarce. Some vague interpretations and classifications of the significant roles of public actors have been provided. A case in point is Kincaid and Overcash's (2001) study, which proposed methods by which to build eco-industrial relationships in the early 2000s, with the authors suggesting that public actors be regarded as representative of an "industrial ecosystem coordinator." Similarly, Von Malmborg (2004) noted that local authorities act as network hubs that initiate, facilitate, and lead local collaborative networks. The public actor aiming to bring organizations together for collaboration has been labeled as an influencer (Costa et al., 2010), a catalyst (Daddi et al., 2016), and a management body (Tessitore et al., 2015) of an EIP. Perhaps the most concrete conception of public actor roles in the EIP-related literature is that proposed by Von Malmborg (2004), who offered the notion of a "knowledge bank" or "knowledge broker," which relates to the transfer of knowledge, information, and ideas to and within public and private actors. Since the publication of Von Malmborg's work, the roles assigned to public actors have increased and diversified, covering multiple functions, such as facilitative, planning, investment, and administrative roles (Yu et al., 2015a). As Kirsop-Taylor and Hejnowicz (2020) stated, public actors working on environmental issues have recently experienced "significant executive and public pressures to take on additional roles such as advocates, provisioners of services and innovators." An issue that has yet to be explored, however, is into what kind of roles the diversification has led in practice thus far.

Another deficiency in research is the limited exploration of the ways by which public actors use different approaches to engaging and interacting with EIPs. The characteristics of the practical manifestations of roles should be expounded in detail because these roles can be executed in numerous ways and by different public actor entities. Similar to Von Malmborg's (2004) research, where public actors' roles in public–private collaboration were noted to be defined in a general manner in the literature, extant scholarship has been unclear as to precisely *how* public actors act or should act when they involve themselves with EIPs.

The existence of different public actor roles also possibly engender different organizational models and structures in EIPs—yet another insufficiently explored topic (Parida and Wincent, 2019). The most frequently referenced role is the central actor, which manages an EIP and aims to maintain and promote sustainable actions within the institution (see, e.g., Daddi et al.'s (2016) study on public management bodies in Italian EIPs). The central actor role is interpreted as reflected by a "hub firm," "champion," "lead organization," and "orchestrator" (Paquin and Howard-Grenville, 2013). In the present work, the central actor is referred to as the "central organization" that has a vital role in successfully organizing an entire EIP (an issue especially explored in Study 2).

3. Methods

The purpose of this study is to explore the public actor and its roles in EIPs: what roles (*RQ1*) public actors may have in an EIP and what kind of actor structures (*RQ2*) relate to the roles. Correspondingly, the study is divided into two parts. In Study 1, the public actor roles in EIPs are examined through an extensive multiple case study based on qualitative secondary data of 20 EIP cases around the world. In Study 2, the public actor roles and the related structures are analyzed and showcased through a focused multiple case study of four national EIP cases from Finland. Next, Studies 1 and 2 are described in detail.

3.1. Study 1: extensive multiple case study

In Study 1, an extensive multiple case study was conducted to explore the public actor roles in EIPs. Using multiple cases permits broader exploration of the research questions and allows more detailed theoretical observations to be made (Eisenhardt and Graebner, 2007).

Purposeful sampling strategy was chosen in the form of theoretical sampling. The research aimed to develop rather than test a theory, for which purpose the theoretical sampling method is appropriate (Eisenhardt and Graebner, 2007). The case selection in Study 1 was based on the EIP lists provided by Gibbs and Deutz (2007), Erkman and Van Hezik (2016), and Bellantuono et al. (2017). In qualitative studies, the focus is generally on a relatively small sample selected for a very specific purpose (Patton, 2015, p. 264). Therefore, a sample size of 20 was considered sufficient to be studied.

The selected 20 cases were studied using the existing secondary data; this is a common and acknowledged source of information to be used (Yin, 2009, p. 103). For case selection, a preliminary aim of selecting 10 cases representing Western countries and 10 cases representing Asian countries was set. This kind of planning of the sample size in advance is not uncommon owing to researchers' limited resources and time (Eisenhardt, 1989). Moreover, Western and Asian countries were considered to represent two major (opposite) CE ideologies (see, e.g., McDowall et al., 2017). Therefore, the very western-countries–oriented EIP lists were manually complemented by four Asian cases: Kawasaki Zero-Emission Industrial Complex, Rizhao Economic and Technology Development Area (REDA), Suzhou Industrial Park (SIP), and Ulsan Eco-industrial Park. Finally, 20 cases that can almost evenly be divided into the so-called European and Asian cases were chosen for further examination. The cases are presented in Table 1 below.

When examining the public actor roles in EIPs, the adapted principles of qualitative content analysis and typological analysis were used. Qualitative designs often serve as the first step to analyze a phenomenon and should be further developed by quantitative approaches when necessary (Schilling, 2006). Here, the inductive approach, in which particular instances are observed and then combined into a larger unit (Chinn and Kramer, 1999), was used. Following this method, the case material was first analyzed and issues of public involvement were labeled based on the used public means and their purpose (e.g., financial instruments for preserving the system). The labels were then combined into wider, distinct themes. This resulted in six public actor roles in EIPs.

3.2. Study 2: focused multiple case study

In Study 2, a focused longitudinal multiple case study on four Finnish EIP cases was conducted, which provided a deep understanding on how public roles actualize within a same EIP and are played by an individual public actor. Indeed, a multiple case study is "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence" (Robson, 1994, p. 5). Using different cases for Studies 1 and 2 provided a possibility for data triangulation, improving the validity of the research. Therefore, Study 2 first validates the findings in Study 1 by closely examining and showcasing the public roles within the same EIP in four cases. Second, Study 2 explores the structures in which the different roles may occur and therefore considers the research question 2.

Study 2 relied on a purposeful sample of four national EIP cases from Finland chosen based on access to data and the pre-assumptions of their high representativeness of the studied phenomenon. A deductive approach, in which the selected case manifestations help to examine and elaborate the studied theoretical construct, its variations, and its implications (Patton, 2015, p. 288), was chosen. To enable feasible and focused research, in each of the four cases, the most prevalent public actor within the EIP, namely the central organization, was considered. The cases provide significant examples where public actor involvement in the industrial CE system is undeniably considerable.

Studying the inner actor structures of an EIP requires throughout longitudinal knowledge and access to data. This was achieved by selecting easily accessible cases the researchers had already collaborated with. Studying especially Finnish cases was seen to provide a highly representative picture of the latest avenues of public actors in EIPs, as Finland has been at the top of many CE-related lists such as the Environmental Performance Index (EPI) (seventh place in 2020; Yale Center for Environmental Law and Policy, 2020), the Global Cleantech Innovation Index (GCII) (second place in 2017; Cleantech Group, 2017), and the Global Green Economy Index™ (GGEI) (fifth place in 2018; Dual Citizen LLC, 2018). In addition, Finland was the first country in the world to have a national roadmap to CE (Sitra, 2020). In fact, multiple Finnish public actors such as municipalities, regions, and the government have a CE roadmap, strategies, and other manifestations for being involved in organizing for CE (e.g., Moreno and García-Álvarez, 2018).

The cases were studied hands-on through ethnographic follow-up during May 2017–September 2019. This included regularly meeting the representatives of the EIPs, attending workshops organized by them, and visiting the parks. Ten interviews with the key actors (three from top management, four from development, two from operations, and one from research) from each case were also conducted. For comprehensively understanding each case, the primary data was complemented by secondary data such as public documents and EIP-specific reports. Public actor involvements were first captured by identifying the public actors and actions from the data (e.g., a comment related to the topic during an interview, visualization of the EIP structure by an interviewee, and secondary material regarding public decision-making related to the EIP), after which the data were analyzed and the different public actor roles occurring in the cases were identified. The cases with related data sources are presented in Table 2.

Knowledge on ecosystem structures and governance in CE is scarce (Parida and Wincent, 2019), which also applies to the understanding of the diverse actors in EIPs. EIPs comprise multiple collaborating actors and interactions, which requires research methods that identify this variety of actors and make them and their structures visible. Like in Study 1, the adapted principles of qualitative content analysis were used when analyzing the four Finnish EIP cases for actor structures. In qualitative content analysis, the chosen object is analyzed and categorized based on the regularities found within the data. First, a schema of the overall actor structure for each of the cases was created. Then, the

Table 1
Study 1: Analyzed EIP cases with their primary source material.

Name of the eco-industrial park	Domicile	Primary source material	Abbreviation
Burnside Industrial Park	Canada	Liu et al. (2018)	C1
Dalian Development Area (DDA)	China	Yu et al. (2015a)	C2
Devens Eco-Industrial Park	U.S.A.	Veleva et al. (2015)	C3
Ecopark Hartberg GmbH	Austria	Liwarska-Bizukojc et al. (2009)	C4
Fujisawa Eco-industrial Park, EBARA Corporation of Japan	Japan	Morikawa (2000)	C5
Guitang Group	China	Zhu et al. (2007)	C6
Kalundborg Symbiosis	Denmark	Jacobsen (2006)	C7
Kawasaki Zero-Emission Industrial Complex	Japan	Van Berkel et al. (2009)	C8
Kwinana Industrial Area (KIA)	Australia	Harris (2007)	C9
Nanning Sugar Co., Ltd.	China	Yang and Feng (2008)	C10
National Industrial Symbiosis Programme (NISP)	United Kingdom	Paquin and Howard-Grenville (2013)	C11
Rizhao Economic and Technology Development Area (REDA)	China	Yu et al. (2015c)	C12
Santa Cruz	Brazil	Elabras Veiga and Magrini (2009)	C13
Shenyang Economic and Technological Development Zone (SETDZ)	China	Geng et al. (2014)	C14
Suzhou Industrial Park (SIP)	China (Singapore)	Yu et al. (2015b)	C15
Tianjin Economic-Technological Development Area (TEDA)	China	Wang et al. (2017)	C16
Uimaharju Industrial Ecosystem	Finland	Korhonen (2005)	C17
Ulsan Eco-industrial Park	South Korea	Park and Won (2007)	C18
Value Park	Germany	Valentino (2015)	C19
Vreten Park	Sweden	Valentino (2015)	C20

Table 2
Study 2: Analyzed EIP cases and related data sources.

Name of the eco-industrial park	Central (public) organization	Interviews with key actors	Observation, ethnography	Secondary source material
Ekomo Eco-industrial Centre, Ämmässuo; Helsinki Region, Finland (HSY 2020)	Helsinki Region Environmental Services Authority HSY	2	Visiting the park, attending a workshop discussion, attending an online workshop (2), free-form discussion with a key actor, and attending monthly meetings on project updates (ca. 20)	Annual reports, completions of the city council and other institutes, news, web pages, and seminar presentation by the central organization
Rusko Waste Treatment Centre; Oulu, Finland (Kiertokaari 2020)	Kiertokaari Ltd.	3	Visiting the park, attending monthly meetings on project updates (ca. 20), free-form discussions with key actors, and attending an online workshop	Annual reports, completions of the city council and other institutes, news, web pages, and seminar presentations by the central organization (3)
ECO3 Kolmenkulma Eco-Industrial Park; Nokia, Finland (ECO3, 2020)	Verte Ltd.	2	Visiting the park, attending workshop discussions (4), free-form discussions with key actors, and attending meetings of the park members and stakeholders (2)	Annual reports, completions of the city council and other institutes, news, web pages, journal article, project report, and seminar presentations by the central organization (3)
Topinpuisto Circular Economy Hub; Turku, Finland (Topinpuisto 2020)	Lounais-Suomen Jätehuolto Ltd.	3	Attending monthly meetings on project updates (ca. 20) and attending an online workshop	Annual reports, completions of the city council and other institutes, news, and web pages

structures were further analyzed with emphasis on public actors and their roles in the systems. As a result, examples of the relations between different public actor roles and actor structures were identified. Study 2 therefore shows how the identified roles can be situated in an EIP and how the park is structured. For illustrating the relationships between the studied EIP actors, a software program Kumu (see Kumu 2020) for visual network mapping enabled analyzing, identifying, and visualizing the actors, particularly the public actors involved in EIPs, as well as the relationships between them.

4. Results

Next, the results of Studies 1 and 2 are presented. The recognized roles for public actors in EIPs are first proposed. Then, a closer examination on the occurrence of the roles within EIP actor structures are considered.

4.1. The many roles of public actors in eco-industrial parks

Based on the examination of 20 EIP cases (Study 1), six distinct public actor roles were identified: *operator*, *organizer*, *financer*, *supporter*, *policymaker*, and *regulator*. The roles depict the means of public actors and the interfaces of public involvement in an EIP. The roles represent different ways to contribute to and be involved in the EIP. It is common for the same public actor to simultaneously have several roles within/toward the EIP (see Chapter 4.2). Moreover, several public actors can be involved in the EIP with different or even overlapping roles, including public actor types such as public companies, local municipalities, cities, and national governments. Next, the roles are presented with examples from the studied cases (for explanations of the case abbreviations, see Table 1).

The *operator* concentrates on the everyday operations and functions of an EIP. The public actor is strongly present and involved in the park and has direct interaction with the park members. An operator can guide the development of the park area (C3), assess and inspect the work of the park members (C15; C16), or manage the park infrastructure (C3). The more collaborative approaches include mutually promoting and enhancing industrial symbiosis (C11), providing environmental services for the members (C16), and organizing the dispersed knowledge resources in the park (C16).

The *organizer* affects the organization framework – i.e., the structural mechanisms of the EIP. The organizer oversees that the structural qualifications for the functioning of the EIP are met. This

can include launching the entire EIP (C3; C4; C13; C15; C20), setting the management structures (C18), or making formal agreements with the involved companies regarding their commitment to the park and sustainability (C13). An organizer may also organize the EIP by allocating different responsibilities between the park members and itself (C7).

The *financer* is responsible for the public financing applied to the EIP. The instruments include indirect financial incentives as well as direct economic support for the park members. The financer can offer the park members beneficial energy prices and infrastructure (C4) or even services free of charge (C11) to promote sustainability goals. Direct funding instruments include financial support toward voluntary sustainability actions (C8; C12), financing for sustainability projects (C11), and covering the operation costs of the park (C1).

The *supporter* offers support functions for the EIP. The supporter has a partner-like mentality and offers help and expertise for the park in a supportive manner from the outside of the park. For example, public research institutes can collaborate with the park members (C9), or the public authority and park members can collaborate on development projects (C8; C11; C12). The supporter may also advance sustainable actions in the EIP through by-product exchanges and processing contracts with the companies (C4; C7; C14; C17).

The *policymaker* has a sustainability policy/agenda and applies it to the EIP. The policies include both encouraging guidelines and strict standards based on the national, regional, or park-specific level. The policymaker can co-develop the policies and programs with the park members (C3; C13) by following the frames set by, for example, regional industrial symbiosis programs (such as transforming industrial areas into green ones (C4; C18)) or national policies (C10; C12; C14; C18). The sustainability agenda can also be executed in a top-down manner when a public actor controls the acceptance of a company to a national sustainability program (C2; C6; C8) or oversees that the public sustainability policies are being followed in the park (C8; C10; C12).

The *regulator* interacts with the EIP through legislative and regulative means aimed toward the park or its operating environment. Legislative means are used as supportive guidelines that encourage and help the park members to achieve sustainability (C2; C8). Regulative means are detailed standards and demands that the park members must follow. These include, for example, strict requirements for environmental quality (C6; C12; C15; C18) and compliance with the national regulation (C14).

4.2. The roles of public actors and related structures within an eco-industrial park

The results of Study 2 show how the six roles (identified in Study 1) occurred in four national EIP cases: a) the same public actor simultaneously plays several roles in an EIP and b) each of the roles occurs within certain EIP structure. The identified roles and structures are next depicted in detail and finally summarized in a visual presentation (Fig. 1). In each case, the roles where the (public) central organization is the most prevalent and active public actor are considered. This means that although the central organization may have other roles within the EIP, it is not the most significant representative of those roles.

In *Case 1—Ekomo Eco-industrial Centre, Ämmässuo*, the central organization is the public waste management company around whose operations and territory the EIP has evolved. The waste management company has its own duties deriving from national waste regulation, but private companies can also join its wide treatment area. The central organization is thus an *organizer* because it provides the infrastructure and facilities for individual companies to process their own side streams and have by-product exchanges in the area. The park members operate independently, although the central organization is responsible for the coordination actions of the park, such as allocating facilities for companies and controlling the visits to the area. The central organization is thus also an *operator*. In addition, the central organization is a *supporter* when, in addition to its own responsibilities, it promotes cooperation between park companies, provides training for companies and citizens, and applies for project funding for the development of the park services.

In *Case 2—Rusko Waste Treatment Centre*, the central organization is also a public waste management company. However, here the entire EIP is solely built around this actor, its processing area, and legal obligations, i.e. its internal actions. Therefore, the central organization has the role of an *operator*. Legislative obligations largely determine the activities and development projects of the central organization, but the central organization also provides an opportunity for private companies to process their waste streams alongside public streams. In this way, the central organization is a *supporter*, as it is responsible for the processing facilities, equipment, and services in the park. The operation of the park is financed by the revenues from waste disposal fees; therefore, the central organization is also the *financer* of the park. In addition, the central organization invests in several sustainability projects on a yearly basis.

In *Case 3—ECO3 Kolmenkulma Eco-Industrial Park*, the central organization is a public development company owned by the local municipality. The company aims to promote the vitality of the municipality by enhancing the business opportunities for the companies around its territory. The development company coordinates the activities within the EIP; the EIP is a platform for cooperation provided for private companies by the municipality. The central organization is the *operator* and responsible for the park operations. For example, it negotiates with the companies interested in locating their operations in the area and requires the companies to have a well-designed and established business model. Moreover, the central organization actively develops the park to promote business opportunities for the park members. In this role as a *supporter*, the central organization, for example, organizes joint meetings for the park members and companies interested in joining the park as well as provides advice to companies on funding applications.

In *Case 4—Topinpuisto Circular Economy Hub*, the central organization is a public waste management company. The EIP has emerged within the area of an old public landfill, where the central organization and private companies process various by-products side by side. The central organization with its waste treatment area is therefore an *organizer*. The park members operate fairly independently, but the central organization has taken the role of an active *operator* that seeks to develop a common vision and brand for the area. In addition to the physical park area, the central organization considers the EIP to consist of a wider network of cooperation, for which the park is a platform to promote sustainable operations. The central organization is also a *supporter* because, alongside its mandatory duties, it provides services such as meeting rooms and joint events for the park members. The central organization has planned to have a visitor centre in the park.

To summarize the findings from the four national EIP cases, the roles of each public central organization are presented in Table 3. The EIP actor map (Fig. 1) shows the positions of different public actor types in the cases and what roles they might play. Overall, when considering how the public actor roles manifest structure-wise within the EIP, there seems to be interdependency between the roles and physical locations of the public actors in relation to

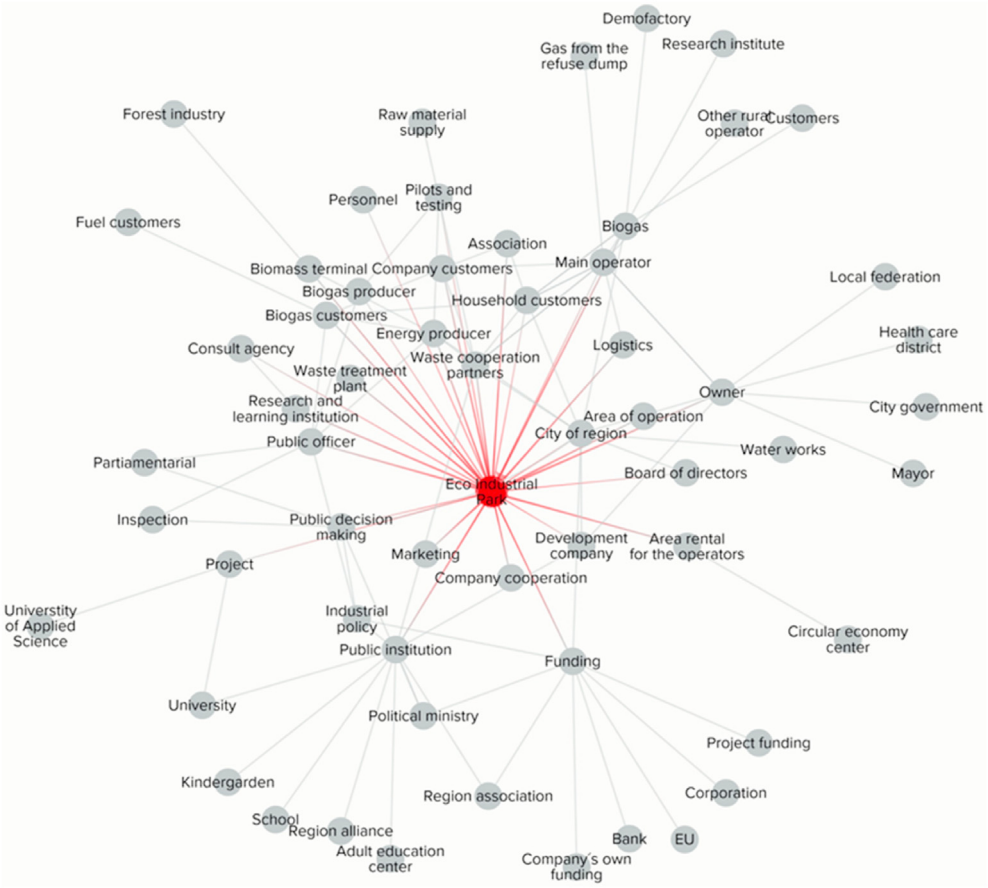


Fig. 1. Public actors in the four examined Finnish EIP structures. The most permanent relationships of the central organization of the EIP are showed and colored with red, whereas other EIP actors are illustrated in gray.

Table 3
The roles of the public central organization in each of the cases in Study 2.

Case	Central organization as
Ekomo Eco-industrial Centre, Ämmässuo	operator, organizer, supporter
Rusko Waste Treatment Centre	operator, financer, supporter
ECO3 Kolmenkulma Eco-Industrial Park	operator, supporter
Topinpuisto Circular Economy Hub	operator, organizer, supporter

the EIP.

Based on the findings, the roles seem to be divided into two types based on the location of the public actor. *Operator*, *organizer*, and *supporter* represent the roles of a public actor located within the EIP or in its immediate sphere of influence. In the four cases, these roles were usually adopted by the public central organization. A presence in or close to the park is needed because in these roles, the public actor may, for example, provide the physical area in which the park is located and offer public side streams for park companies, for which hands-on knowledge about the park is needed.

Financer, *policymaker*, and *regulator* are the roles often adopted by public actors located outside of the physical EIP area. The regulator is usually a macro-level actor such as the national government, who implements national policies affecting the overall legal context of EIPs. The financer can be a meso- or macro-level institution such as the local municipality, international funders, or research institutes. The policymaker affects the EIP on micro level because its policies guide the central organization of the EIP; the policymaker can be represented by a local city or even national government through its legislation and policies.

5. Discussion and conclusions

The two multiple case studies generated new insights about the public actor roles in EIPs. The key findings are: 1) The entities representing the public actors involved in EIPs are divers (e.g., public development company, local municipality, national government, state legislature, and regional environmental agencies were recognized in the studies). 2) Public actors can have diverse roles (*operator*, *organizer*, *financer*, *supporter*, *policymaker*, and *regulator*). 3) The same actor can simultaneously have several roles within the same EIP (e.g., the public actor can independently lead the development of common vision and brand for the park as an operator, and simultaneously provide collaborative services such as meeting rooms and joint events for the park members as a supporter; as in Study 2). The results show that the role of public actors in EIPs is not only significant but also often multifaceted and crucial for an EIP to operate at its full potential. Next, the theoretical and practical contributions of the findings are discussed in detail. Limitations of the research and avenues for future research are also presented.

5.1. Theoretical contributions

Previous studies generally defined public actors in EIPs as enablers (Gibbs and Deutz, 2007), coordinators (Tessitore et al., 2015),

influencers (Costa et al., 2010), or catalyzers (Daddi et al., 2016). The six roles recognized in the present research align with those identified in the aforementioned studies as, collectively, the roles represent public actors as wielding the active and significant hand of an enabler that has multiple means of developing EIPs. Similarly, the recognized roles align with the ones presented by Uusikartano et al. (2020) in their more general study on public agency roles in industrial CE ecosystems. The analysis in Study 2, in turn, is consistent with the argument that public support is a clear catalyst of more sustainable practices in EIPs (Bellantuono et al., 2017).

This study shed light on how public actors play their significant roles in practice. Previous studies provided a cornucopia of means for public involvement but included few interpretations of public actors' roles in EIPs. Contrastingly, the current work integrated means and roles by presenting six functions based on the characteristics of the means used by public actors and the way that these agents use them. The recognized roles also reflect a more detailed interpretation of previously published results on public actor roles in EIPs (see Section 2): The legislative means recognized earlier are represented here as a *regulator*, the economic means as *financer*, the coordinating means as *operator/organizer/supporter* and the policy means as *policymaker*. Put differently, the legislative, economic, coordinating, and policy means are connected to their implications (Study 2, which examined how roles occur in different actor structures).

The diversity of public actor entities identified in this work aligns with the state legislatures, local municipalities, and state governments mentioned in previous studies (see Section 1). The results further expanded the definition of EIPs, showing that collaboration among organizations external to EIPs and situations where all organizations are uncollocated in EIPs are also possible—a finding that contradicts an argument made in industrial ecology research (see Ruggieri et al., 2016).

The six roles represent concrete means and epitomes of interfaces between the public actors and EIPs. Fig. 2 illustrates these roles, examples of corresponding means and inter-role relations. *Operator*, *organizer*, and *supporter* pertain to roles within an EIP, whereas *financer*, *policymaker*, and *regulator* refer to roles often adopted by public actors located outside of a physical EIP area (Study 2). *Operator* and *supporter* seem to be the most prevalent/inevitable presence in EIPs (Table 3). These roles and the means they represent can encompass the most vital elements of successful EIP functioning, as suggested by their presence in all studied public central organizations. Their occurrence in the cases showed that public actors play an overall crucial role in EIP functioning. Moreover, operator and supporter roles are generally represented by public actors located within EIPs, suggesting that actors wanting to directly influence EIPs should closely involve themselves with these parks.

The diversity and multiplicity of the roles showed that the examination of public actor involvement in EIPs should not revolve around single-role assumption but a combined presence grounded in several different roles. A single public actor can simultaneously assume a number of (overlapping) roles even within the same EIP—an idea also presented by Yu et al. (2015a). This was the case in Study 2, where the public actor roles were found to be very strongly centralized to one public actor: the central organization of an EIP.

5.2. Practical implications

In practical terms, the classification of roles provided in Fig. 2 serves as a pragmatic tool, a catalogue of the means for public actors in EIPs. From the catalogue, a public actor can choose the most suitable means to promote CE in each context. The classification represents the critical elements for functional public actor involvement in EIPs because it is based on the results from different, established EIPs and the most used means of public actor involvement in them. The classification also helps practitioners

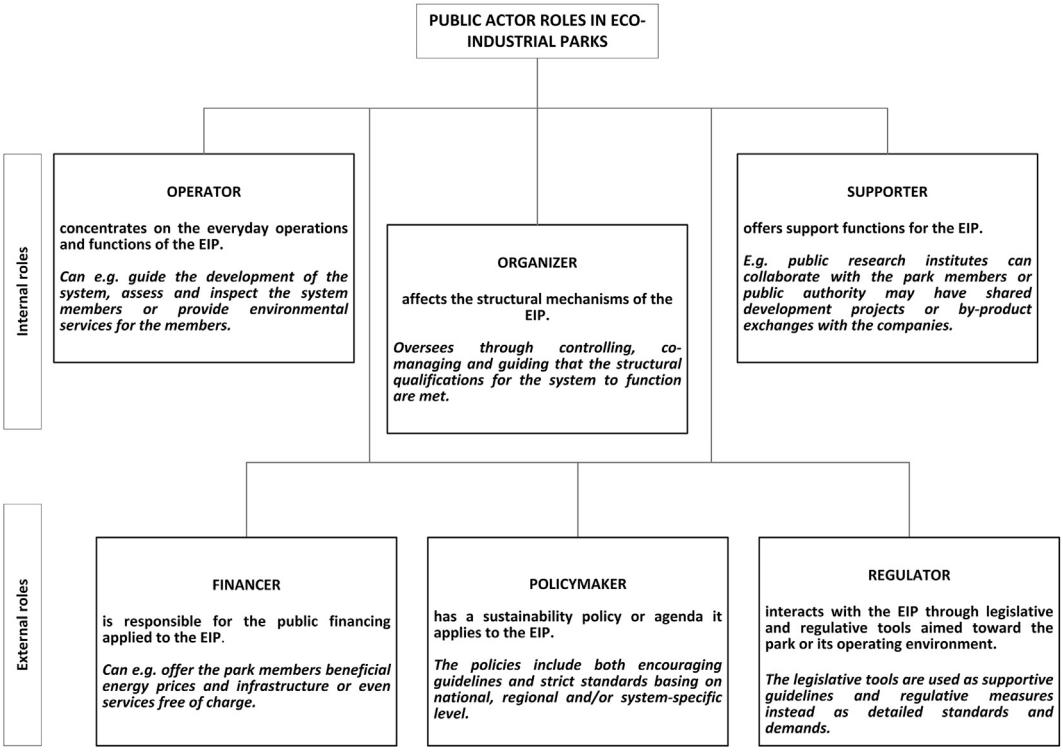


Fig. 2. Classification of public actor roles.

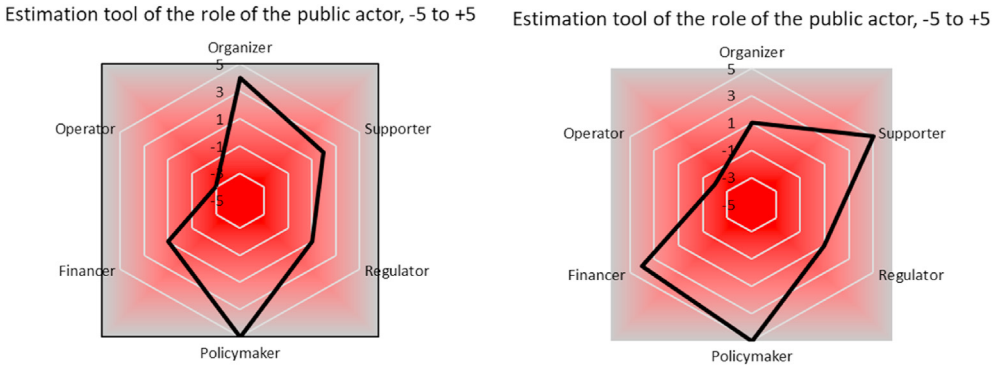


Fig. 3. Example illustrations of the tool for public actors to recognize their current role repertoire.

such as EIP administrators to understand the nuances of the roles of public actors in industrial contexts—that is, to understand the laws of the society in which they are operating.

The classification of roles in Fig. 2 enables the development of a pragmatic tool for public actor role assessment. This tool helps to recognize the bigger picture of the role repertoire of public actors in a concrete way. When using the tool, the evaluator selects a value between −5 and + 5 for all six identified public actor roles based, for example, on a professional statement or an intuition of the representative of the public actor and/or private actors of the EIP. Then, the emphases between the public actor roles are made visible through a graphic illustration. Examples of such illustrations are shown in Fig. 3.

5.3. Limitations and future research

The research has some limitations based on the chosen research methods. In the analysis of the 20 EIP cases in Study 1, the types of public actions that occurred in an EIP were extensively studied. The case material of the 20 EIP cases spread over different time periods—with some case material being over 10 years old and some very recent—and provided a look into the individual activities identified from the material. Study 1 therefore does not provide an overview on what roles and activities can actually co-exist within an EIP. This issue was addressed in Study 2, although the case material focused on a relatively short period of time—a snapshot—meaning that no interpretations about the temporal incidence and development of public actors can be made on the basis of the research. Indeed, the picture of the studied phenomenon created through qualitative content analysis is always in principle contextual and not objective (White and Marsh, 2006).

The cases in Study 1 represent a sample of EIPs around the world, increasing the generalizability of the roles across regions (although country-specific variances may occur). However, the recognized manifestations of the roles presented in Study 2 should be examined with caution: The cases are from Finland, meaning the results presented are under the influence of context-specific factors present in each case. The generalizability of the presented results could be improved by a similar research with a bigger sample, allowing the examination of public actors in other industrial settings than EIPs. Also, in EIPs, the actions are mainly industrial symbiosis–related such as by-product exchanges and side stream flows between co-located companies. Therefore, studying whether different cascading approaches differ from each other in terms of public involvement is necessary. Similarly, a series of longitudinal studies using with up-to-date data can provide valuable insights into the temporal nature of public actors in EIPs.

The results of this study raise further questions. How do the different public actor roles within the same EIP affect each other when being represented by the same or several public actors? Is there a connection between public actor types (e.g., municipality, city, and government) and certain roles? Does the occurrence of the roles differ between cultures? Do companies experience some of the roles in different ways? These questions would demand more studies on national cases across global regions and operating environments. By exploring these questions, the nuances of public actor involvement and its effects on EIPs and industrial CE in general would be better understood.

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CRediT authorship contribution statement

Jarmo Uusikartano: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – original draft, preparation, Writing – review & editing, Visualization, Project administration. **Hannele Väyrynen:** Methodology, Validation, Formal analysis, Investigation, Writing – original draft, preparation, Writing – review & editing, Visualization, Project administration. **Leena Aarikka-Stenroos:** Conceptualization, Writing – review & editing.

Declaration of competing interest

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

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