This paper was presented at The ISPIM Innovation Conference – Innovating in Times of Crisis, 7-10 June 2020.
Event Proceedings: LUT Scientific and Expertise Publications: ISBN 978-952-335-466-1

Public agency catalysing sustainability transition: the roles and modes

Jarmo Uusikartano*

Tampere University, Korkeakoulunkatu 8, 33720 Tampere, Finland
E-mail: jarmo.uusikartano@tuni.fi

Hannele Väyrynen

Tampere University, Korkeakoulunkatu 8, 33720 Tampere, Finland
E-mail: hannele.vayrynen@tuni.fi

Leena Aarikka-Stenroos

Tampere University, Korkeakoulunkatu 8, 33720 Tampere, Finland.
E-mail: leena.aarikka-stenroos@tuni.fi

* Corresponding author

Abstract: Value creation in circular economy (CE) is a result of co-creation. In industrial context, the collaboration has been studied extensively on company-to-company basis, but related public agency remains unexplored. Still, circular actions happen in societal contexts where public actors and logics are constantly present. The study considers: 1) What roles can a public actor have in industrial CE systems? 2) What are the relationship modes a public actor can have toward a system? The study is relied on multiple case study and qualitative content analysis on the secondary data of international eco-industrial parks. Six distinct roles and two modes for public agency in industrial CE systems were identified. The roles depict the concrete tools used by public actors and the modes the characteristics of these actions. The study provides insights on how public actors can contribute to sustainability transitions and helps practitioners to better understand the premises for public-private interaction.

Keywords: circular economy; sustainability; agency; public actor; roles; collaboration

1 Introduction

The existing linear economy model has proven to be unsustainable for the nature and well-being of Earth's inhabitants (Ghisellini et al. 2016), which calls for sustainability transition toward circular economy (CE) globally. Adopting a CE way of doing business requires companies to change their business models or even create totally new ones (Urbinati et al. 2017). This highlights the importance of collaboration between different agencies when value creation in CE is a result of co-creation. Company-to-company

collaboration has been extensively studied in industrial setting and especially in the form of industrial symbiosis (IS) (see e.g. Ghisellini et al. 2016). This is understandable as the high-volume industrial scale and companies' ability to agile adjustments enable significant contributions to CE. However, it takes two to circular tango; IS happens in societal, public context through collaboration between public and private actors.

The public sector can catalyse the sustainability transition, as all circular actions happen in societal contexts affected by public laws, policies, procurement processes, authorization protocols and so on. Furthermore, CE is a form of sustainability transitions that creates new structures and ways of public administration, which in turn requires new kind of collaboration between actors both in the government and private business systems (see e.g. Isaksson & Heikkinen 2018). IS and related eco-industrial parks (EIPs) even emphasize this factor, for in them, companies often contribute to sustainability targets set by the prevailing social context and public actor (for examples, see Ghisellini et al. 2016). Indeed, there is a call for the consideration of the public sector role in CE systems (Fratini et al. 2019).

With industrial CE systems, we refer to such entities Zucchella and Previtali (2019) call "successful circular economy systems". According to them, in successful CE system: "Relevant innovations are involved, in products, processes, and in the business model, a range of differentiated actors – not only colocated – are engaged, and an orchestrator plays a key role in pursuing and sharing a vision and materializing it into an ecosystemic business model." Here, this concept considers broadly circular constitutions such as "eco-industrial park", "green industrial park", "eco-cluster", "industrial recycling networks" and "eco-center" (see Patala et al. 2014; Wang et al. 2017; Herczeg et al. 2018). The systems approach is important as the new issues actors must consider in CE require cooperation in practice. The issues include closing the material loops, reducing the resources needed and preserving the materials in the loops as long as possible (Antikainen et al. 2017). These often refer to IS, "a web of interdependencies between companies" (Herczeg et al. 2018) calling for multi-actor constitutions, systems.

CE should be seen as a new and different business model where the well-being has its own role apart from resource consuming (Ghisellini et al. 2016). In order to understand successful circular business models, the forms of collaboration and innovations among different actors must be explored better (Zucchella & Previtali 2019). This also considers public authorities, but the forms of public agency in CE are not yet studied properly. The purpose of this study is to provide novel knowledge on the avenues for public presence and influencing in industrial CE systems. Public agency in CE is examined in the context of EIPs that are arguably the most studied circular constitutions where public and private actors often pursue environmental goals and innovations together. The study deliberates in two research questions:

1) *What roles can a public actor have in industrial circular economy systems?*
2) *What are the relationship modes a public actor can have toward an industrial circular economy system?*

2 Current understanding

The presence of the public actor in industrial CE systems is acknowledged in the scientific literature. Many researchers emphasize the importance of public actors in

fostering CE through politics, national initiatives, economic incentives, environmental legislation and raising awareness (Ghisellini et al. 2016). In the context of EIPs, researchers state that publicly supported or promoted EIPs adopt more sustainable practices than the ones with limited public support (Bellantuono et al. 2017). On the other hand, some researchers see the public actor as an inhibitor when for example the current legislation is too fixed for new circular experiments. According to Fischer and Pascucci (2017), old and inflexible legislation and linear economy -based investment criteria constrain new innovative actions within CE.

The researches do still not agree how significant the role of the public actor should be in CE. Mulrow et al. (2017) state that public actor's involvement in companies' circular actions can have both positive and negative consequences. According to Wang's et al. (2017) research, local government can have vital role in creating and sustaining IS networks in China although other actors are also needed. Moreover, Yu et al. (2015a) claim that suitable policy instruments together with a combination of publicly controlled and organically developed actions may encourage the transformation of industrial parks into eco-industrial ones. Overall, there is some debate about the superiority between government policy and a free market approach (Walls & Paquin 2015) and the discussion continues.

In addition to the differing levels of public involvement in industrial CE systems, there are also different ways for this involvement to actualize. This is seen in the vague suggestions about different public actor roles in CE. Avenues for public involvement in CE systems cover at least economic, legislative, coordinating and political mechanisms (see e.g. Yu et al. 2015a, 2015b) that the public actor can use in a formal or informal manner. The public actor acts as a support system around which the development of industrial ecology could be built (Korhonen 2001) or even shapes the institutional environment to promote sustainable actions (Zeng et al. 2017). Furthermore, it is suggested that governments should catalyse IS actions in order to promote overall transition toward CE (Velenturf 2017). So, the public actor sets with different mechanisms the tone for industrial CE systems.

The different mechanisms suggest there can be different public actor roles emerging simultaneously within the same CE system. Indeed, local authorities often have many roles such as administrator, investor, planner and facilitator (Yu et al. 2015a), and the portfolio of tools and liabilities recognized for public actors in CE is broad, yet unstructured. Study on the role of public sector in CE systems is needed (Fratini et al. 2019). This study contributes to the need by explicitly focusing on the public involvement in CE in the context of industrial CE systems.

3 Research design

A multiple case study based on qualitative secondary data was conducted in order to recognize the public roles and relationships through which the roles interact with private actors in industrial CE systems. Case study was seen as a natural fit for the purpose, as it 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). When a theory is based on multiple cases, it is better grounded, more accurate, and more generalizable (Eisenhardt & Graebner 2007).

In the study, purposeful sampling strategy was chosen in the form of theoretical sampling. This deductive approach involves finding such case manifestations of the

studied theoretical construct that help to examine and elaborate the construct, its variations and implications (Patton 2015, p. 288). In this study, 20 cases based on existing secondary data were chosen.

Secondary data is a common and acknowledged source of information to be used (Yin 2009, p. 103). For the unit of analysis, EIP was deemed as a unit best representing an industrial CE system in practice at the moment. Indeed, EIPs have been immensely studied and documented during the last few years (see Ghisellini et al. 2016). The selection was based on the EIP lists provided by Gibbs and Deutz (2007), Erkman and Van Hezik (2016) and Bellantuono et al. (2017) and the data availability and representativeness of the cases. Therefore, the aim of this research is to rather develop than test a theory, for which purpose the theoretical sampling is an appropriate method (Eisenhardt & Graebner 2007).

As the observed cases are based on secondary data provided by other researchers, the chosen cases were the ones most studied among the field and therefore including a great deal of existing knowledge. When choosing the cases, a preliminary aim of gathering 10 cases from western countries and 10 cases from Asian countries was set. This is because these areas were considered representing the two major (opposite) CE ideologies (see e.g. McDowall et al. 2017). As the aim was to broadly study the possible roles and modes of public agency, the very western countries oriented EIP lists were manually complemented by four Asian cases, namely Kawasaki Zero-Emission Industrial Complex, Rizhao Economic and Technology Development Area (REDA), Suzhou Industrial Park (SIP) and Ulsan Eco-industrial Park. As a result of the case selection, 20 EIP cases that divide almost evenly into the so-called European and Chinese cases, were chosen for further examination. 20 was considered as a sufficient number of cases to be studied as in qualitative studies, typically the focus is on a relatively small sample selected for a quite specific purpose (Patton 2015, p. 264). The cases are presented in Table 1.

Table 1 Analysed industrial CE system cases and their primary source material.

Name of the eco-industrial park	*Domicile*	*Primary source material*
Burnside Industrial Park	Canada	Liu et al. 2018
Dalian Development Area (DDA)	China	Yu et al. 2015a
Devens Eco-Industrial Park	USA	Veleva et al. 2015
Ecopark Hartberg GmbH	Austria	Liwarska-Bizukojc et al. 2009
Fujisawa Eco-industrial Park, EBARA Corporation of Japan	Japan	Morikawa 2000
Guitang Group	China	Zhu et al. 2007
Kalundborg Symbiosis	Denmark	Jacobsen 2006
Kawasaki Zero-Emission Industrial Complex	Japan	Van Berkel et al. 2009
Kwinana Industrial Area (KIA)	Australia	Harris 2007
Nanning Sugar Co., Ltd.	China	Yang & Feng 2008
National Industrial Symbiosis Programme (NISP)	United Kingdom	Paquin & Howard-Grenville 2013
Rizhao Economic and Technology Development Area (REDA)	China	Yu et al. 2015b

Santa Cruz	Brazil	Elabras Veiga & Magrini 2009
Shenyang Economic and Technological Development Zone (SETDZ)	China	Geng et al. 2014
Suzhou Industrial Park (SIP)	China (Singapore)	Yu et al. 2015c
Tianjin Economic-Technological Development Area (TEDA)	China	Wang et al. 2017
Uimaharju Industrial Ecosystem	Finland	Korhonen 2005
Ulsan Eco-industrial Park	South Korea	Park & Won 2007
Value Park	Germany	Valentino 2015
Vreten Park	Sweden	Valentino 2015

In the multiple case study, qualitative analysing methods, more precisely adapted principles of qualitative content analysis and typological analysis, were used when examining the public actor roles and modes. Qualitative designs serve often as the first step to analyse a phenomenon and should be further developed by quantitative approaches when necessary (Schilling 2006). In qualitative content analysis, the chosen object is analysed and categorized based on the regularities found within the data. Here, the inductive approach, in which particular instances are observed and then combined into larger units (Chinn & Kramer 1999), was used. This applies to public agency in CE as the research field related to it is scattered.

In typological analysis, data is to be organized with the help of a pre-defined framework or dimensions. Against the organizing framework, here the roles and modes, the cases are grouped, empirical regularities examined (Kluge 2000) and possible commonalities searched (Ayres & Knafl 2012). The found public actor involvements in the 20 EIP cases were categorized based on the most prevalent tools and nature of interaction the public actor had in each setting. As a result, six roles and two modes for public agency with examples were identified.

4 Results

Roles through which public agency actualizes in industrial CE systems

Based on the case study of 20 EIP cases, six clear distinct roles of public agency in industrial CE systems were identified. The roles differ from each other on the basis of the avenues and tools through which a public actor influences/contributes to the actions that happen in the system. This way, the roles present simultaneously different interfaces for public-private interaction, i.e. they are avenues for public actors to intervene in circular systems. The six roles for a public actor to play in industrial CE systems are: the *operator*, *organizer*, *financer*, *supporter*, *policymaker* and *regulator*. The roles and related mechanisms and field of engagement are presented in Table 2. It must be noted that the same public actor can have several roles at the same time and there can be several public actors (e.g. local municipality, government, public servants) having different roles within the same system.

The *operator* contributes to the operations of an industrial CE system. The actions of the operator affect how the system operates and functions. The tools of interaction are mostly managemental including both more imperative (e.g. the development of old

industrial area guided by local authority; public departments assessing, accepting and inspecting the system members) and collaborative approaches (e.g. public departments promoting, building and maintaining IS with a partner-like mentality; environmental services provided for the system members).

The *organizer* concentrates on the organization framework of the industrial CE system, i.e. what is the organizational structure of a system and how the operations are organized in it. The organizer contributes to the setting, vision and goals of the system and can even be the initial force launching the CE system (e.g. state legislature created a commission to plan the reuse of the old area). The organization contribution can happen through collaborative acts such as shared public-private management of the system (e.g. the department of the local municipality is responsible for the secretary and visitors of the system). On the other hand, the organizer can have direct controlling and guiding actions within the system (e.g. formal agreements on sustainability goals with companies; selecting the operator).

The *financer* is responsible for the public finance actions implemented toward the industrial CE system. The tools cover financial incentives toward sustainability such as ready-made public infrastructure or beneficial energy prices. More direct financial support for the system members is possible too. This support includes also direct funding such as financial support toward voluntary sustainability actions, funding for sustainability projects, covering the costs of the system operator, or providing services free of charge for the members.

The *supporter* provides support functions for industrial CE systems. Usually, the supporter is physically located outside of the system and has partner-like interaction with the system. The supporter can have by-product exchanges and contracts with the system companies, or there can be state-owned enterprises located in the system. The supporter participates in a collaborative/consultative manner in actions that promote and enhance sustainable actions in the industrial CE system (e.g. public research institutes offering their expertise for companies; mutual development projects with companies).

The *policymaker* has an influence on the sustainability policy/agenda implemented in the industrial CE system. The tools vary from national environmental and sustainability policies to regional IS programs and system-specific agendas. The policies and programs can be co-developed together with system members or executed top-down (e.g. acceptance of a company to a national program; public plans of transforming old industrial areas into green ones). The policymaker often oversees that the system actions are aligned with public sustainability policies.

The *regulator* affects the industrial CE system through legislation and regulation regarding the system itself or its operations context. In a softer approach, legislation is used to guide and encourage system members toward sustainability. This means guidelines through which the regulator affects indirectly the system (e.g. system operator accredited by local authorities). In an imperative approach, even strict regulation is targeted toward the system. Here, detailed rules and standards are used (e.g. strict rules for the environmental qualities of the system members; clear demands for IS; required compliance between the system actions and national legislation).

Table 2 The identified roles, modes and examples of public agency in industrial CE systems.

Role	*Mode*	
	Facilitative	*Imperative*
Operator	The operator of the park belongs to local university. (Burnside Industrial Park, Liu et al. 2018)	In the park, there are different public-based departments that e.g. assess the environmental impacts of the park attendees, determine whether an attendee or project is approved to the park or not, and monitor as well as perform environmental inspections in the park. (SIP, Yu et al. 2015c)
	The commission created by the state legislature guided the redevelopment of the old military base through regulatory and permit-granting actions. Alongside, a quasi-state agency manages the infrastructure, public services and the sale and leasing of real estate within the area. (Devens Eco-Industrial Park, Veleva et al. 2015)	In the park, there are different departments formed by the local authority. They e.g. coordinate and manage the park, measure the pollution rates of the companies, facilitate inter-firm IS opportunities, and organize the dispersed knowledge resources in the park. (TEDA, Yu et al. 2014)
	The program, executed by 12 semi-autonomous regional offices, performed actions from promoting and building the IS network to maintaining and co-developing it. (NISP, Paquin & Howard-Grenville 2013)	The main operator of the park is a local government-owned non-profit organization that provides environmental services for local companies. It is the core of the IS coordination network as it acts as a collaboration platform between government departments and foreign organizations. (TEDA, Wang et al. 2017)
Organizer	The state legislature created a commission to plan the reuse of the base, i.e. to generate vision and goals for the park. (Devens Eco-Industrial Park, Veleva et al. 2015)	The park was established by the local municipality. (Ecopark Hartberg GmbH, Liwarska-Bizukojc et al. 2009)
	A department of the local municipality is responsible for the secretary and visitors of the area. (Kalundborg Symbiosis, Kalundborg Symbiosis 2019)	The park was founded by the local municipality. (Vreten Park, Valentino 2015)
	The local municipality catalyzes contacts between the park members. (Ecopark Hartberg GmbH, Liwarska-Bizukojc et al. 2009)	The park was established when industries located in the industrial district signed a formal agreement with the government to be part of a state government initiative aiming for sustainable development. (Santa Cruz, Elabras Veiga & Magrini 2009)
		The park is a government-to-government project between two countries. In practice, the park is located in one country, but is has been co-developed together with other country that has special knowledge on the subject. (SIP, Yu et al. 2015c)
		The eco-transformation of the park has been government-driven and guided by national environmental policies. (TEDA, Wang et al. 2017)

		The operator of the park is selected by companies and local municipality government. (Ulsan Eco-industrial Park, Park & Won 2007)
Financer	The local government provides financial incentives for the development of IS. (REDA, Yu et al. 2015b)	The public actors on the municipality, province and federal level together cover the costs of the main operator of the park. (Burnside Industrial Park, Liu et al. 2018)
	The local municipality offers the infrastructure and beneficial energy prices for the park members. (Ecopark Hartberg GmbH, Liwarska-Bizukojc et al. 2009)	The major deal of the program funding came from the government with the aim of finding new ways to remain economically competitive under the changing and tightening regulatory environment. (NISP, Paquin & Howard-Grenville 2013)
	The eco-transformation of the area was based on voluntary actions performed by the enterprises and financially supported by the national government. (Kawasaki Zero-Emission Industrial Complex, Van Berkel et al. 2009)	
	The actions and services the national IS program provided were free of charge for the companies. (NISP, Paquin & Howard-Grenville 2013)	
Supporter	The park-located services such as shops, cafés, law offices and cinema are used by the park members and the inhabitants of the municipality. (Ecopark Hartberg GmbH, Liwarska-Bizukojc et al. 2009)	The municipal wastewaters are treated in the wastewater plant of the park. The park also sells the surplus electricity to the national grid. (Uimaharju Industrial Ecosystem, Korhonen 2005)
	There are by-product exchanges and steam and heat contracts between the park companies and the local municipality. (Kalundborg Symbiosis, Jacobsen 2006)	The over 1 300 enterprises located in the park include also state-owned enterprises. (SETDZ, Geng et al. 2014)
	The municipal waste collection has been involved in the recycling projects in the area. (Kawasaki Zero-Emission Industrial Complex, Van Berkel et al. 2009)	
	In the park, the involved companies form groups that study and resolve social, environmental and economic problems, which ultimately leads to strong public-private relationships that benefit both the companies and the local community. (Vreten Park, Valentino 2015)	
	The operator of the park liaises with the public authorities and other stakeholders. It has e.g. collaborated with a technological university in order to enhance the realization of IS in the park. (KIA, Harris 2007)	

	The national environment agency worked together with the program to build awareness of IS. (NISP, Paquin & Howard-Grenville 2013)	
	The local authorities have also participated directly in IS promoting. For example, the local government has organized a society of ecological companies. (REDA, Yu et al. 2015b)	
Policymaker	The local authorities and coordinating entities have tried to answer the needs and challenges of the park companies through sustainability policies, regulations and programs. (Devens Eco-Industrial Park, Veleva et al. 2015)	The park was established by the state legislature as an act to reuse the former military base. (Devens Eco-Industrial Park, Veleva et al. 2015)
	The program was the first national-level IS program in the world. The aim was to promote IS as a key policy tool for the industry and government to help the whole country reach sustainable economy. (NISP, Paquin & Howard-Grenville 2013)	The park is a result of the redevelopment aims of the local industrial properties initiated by the local municipality and supported by the federal government, the EU and the local district. (Ecopark Hartberg GmbH, Liwarska-Bizukojc et al. 2009)
	The frames for the EIP program were co-developed by the environmental protection agency of the city, state government, local university, community and private sector constitutions. (Santa Cruz, Elabras Veiga & Magrini 2009)	The park area has been allocated to companies by local authorities based on the aspect of leading environmental technologies and practices. (Kawasaki Zero-Emission Industrial Complex, Van Berkel et al. 2009)
		The vital force for the redevelopment of the industrial area was the governmental eco-town program. The program was aimed to ground innovative recycling actions within the aging conventional industry clusters. Under the program, the local government has guided the local industries toward more environmentally friendly actions. (Kawasaki Zero-Emission Industrial Complex, Van Berkel et al. 2009)
		The park became a national demonstration EIP as it was selected by the national commission. (DDA, Yu et al. 2015a)
		The national guidelines create a frame based on which the management of the park has created its own guidelines to help accomplish the sometimes strictly binding national policy goals. (DDA, Yu et al. 2015a)
		The park was approved as a national eco-industrial demonstration park due its good compliance with the national policies. (Guitang Group, Zhu et al. 2007)

		The strong national policies toward pollution prevention and resource efficiency have guided the development agenda of the private park. (Nanning Sugar Co., Ltd., Yang & Feng 2008)
		The transformation of the park toward an eco-industrial one has been strongly led by the national policies, according to which the management committee of the park has developed the park concept. Moreover, in the early phase, most of the IS performances were formed through the direct or indirect guidance of the governmental agenda. (REDA, Yu et al. 2015b)
		Alongside the national policies, the local city government has set its own policies for sustainability and designed its own implementation plans to develop CE within its area. (REDA, Yu et al. 2015b)
		The park has been established according to the national economic and technological policies. There is a strong national agenda guiding the park. (SETDZ, Geng et al. 2014)
		The national policies are accompanied by province-level policies such as a fund for implementing cleaner production procedures in the companies. (SETDZ, Geng et al. 2010)
		The park is part of an ongoing national development project, where the aim is to transfer traditional industrial parks into eco ones. The 15-year EIP plan has concrete steps according to which the industrial parks are being transformed. (Ulsan Eco-industrial Park, Park & Won 2007)
Regulator	The symbioses in the park are on some extent result of recycling-oriented thinking that has its grounding in the local legislative framework. (Kawasaki Zero-Emission Industrial Complex, Van Berkel et al. 2009)	The main economic motives for the park companies to pursue IS are the strict regulations, tax preferences, financial subsidies and benefits from material substitution. (REDA, Yu et al. 2015b)
	The municipal government has accredited a committee to lead the development and management of the park. The committee does not have legislative rights, but it implements guidelines and policies on the park. (DDA, Yu et al. 2015a)	The somewhat strict and demanding national legislation concerning the sustainable development of the sugar industry affects the actions of the park. (Guitang Group, Zhu et al. 2007)
		In the park, there have been strong actions toward cleaner production in order to comply with the national legislation and maintain a good environmental image. (SETDZ, Geng et al. 2014)

		There is a lot of regulation directly guiding the actions the park departments, especially the public ones, pursue. Overall, the regulation in the park has increased and become more demanding. It even pushes the companies to implement more environmentally friendly actions in their production. (SIP, Yu et al. 2015c)
		The national government has determined strict standards for the environmental quality of the industries in the park. (Ulsan Eco-industrial Park, Park & Won 2007)

The characteristics of the relationships in different roles – the two modes

In the identified six roles, the premises for public interaction seemed to vary in regard to the used tools and the nature of public-private relationships. In fact, two modes – **facilitative** and **imperative** – for public agency were recognized. When the presented roles depict the public actions, the modes represent the characteristics of these actions. The modes differ from each other based on the level (direct – indirect) and way (definitive – supportive) of involvement and engagement in the industrial CE system actions. In both modes, the public actor is active, but the means to interact with the system differ evidently. The modes and their nature in each of the six public actor roles are presented in the previously mentioned Table 2.

In the **facilitative** mode, the public actor uses indirect supportive and encouraging tools to enhance CE actions in the system. The presence of public agency is not so prominent, but the public actor stimulates the system in the background. The public actor creates propitious frames, opportunities and incentives such as infrastructure and environmental services for sustainable actions. The subtle tools include also financial incentives, beneficial prices, sustainability promoting legislation and advisory CE road maps for companies. The facilitative public actor is usually located outside of the system, which naturally results in such collaborative interaction with the system where the public actor is a partner/customer of the system. The facilitative mode is especially typical for the roles of *financer* and *supporter*.

In the **imperative** mode, the public actor uses direct imperative tools to enhance CE actions in the system. The presence of public agency is definitive, and the public actor actively intervenes with the system. Moreover, the imperative actor is usually the initial force, primus motor for the organization of the system. This presence often lasts after the initiation as well, and the imperative actor is present in the CE system even in physical manner (e.g. as the operator; public enterprises located in the system). In the system, the actor uses decision-making power and controls, manages and assesses the system members. Alongside the controlling actions, the public actor can cover the costs of some environmental actions in the system or provide inputs such as waste waters for the companies. In imperative mode, the public actor has a strong agenda based on public policies (e.g. programs for transforming old industrial areas into eco ones; national eco-industrial demonstration park programs) and regulation (e.g. strict standards for emissions) that the system members must obey or are willing to obey in order to receive

public fame and respect. The imperative mode often occurs in the roles of *policymaker* and *regulator*.

Although the facilitative and imperative modes are somewhat opposites of each other, they should not be seen as dichotomous. Namely, the same public actor can have different modes in different roles or even within the same role. Moreover, the division is not clear-cut, and the modes should be seen as two opposite ends of a continuum depicting the level and way of the public engagement in industrial CE systems. In fact, in the middle of this continuum, there is a more passive state where the public actor does not necessarily have significant implication in the system. There were occasions in the case sample where the public actor was not willing or able to promote circular actions. Such examples are the EIP Santa Cruz where the public actor withdrew entirely from the system (see Elabras Veiga & Magrini 2009) and EIPs Fujisawa Eco-industrial Park, EBARA Corporation of Japan (see Morikawa 2000) and Value Park (see Valentino 2015) that are totally private projects. However, the mode "passive" needs to be addressed better in future studies.

5 Discussion

The paper responds to the call of deeper examination of CE, circular business models and the forms of collaboration and different roles in EIP (e.g. Zucchella & Previtali 2019; Fratini et al 2019). The study offers novel information and guidance on how public agency can promote sustainability-oriented CE operations and innovations in the interface between the public and private sector. Furthermore, it provides a picture of the current ways the public actors are interacting with the private actors in industrial CE systems. By making the mechanisms more visible, the study provides better tools for managing public-private collaboration and therefore sustainability transitions.

Theoretical contribution

What roles can a public actor have in industrial circular economy systems? For now, knowledge about bringing CE into practice is still scarce (Leising et al. 2018). There is a call for study on different agencies in CE and their roles in this transition. This also considers the public sector, and study on the roles of public sector in CE systems is needed (Fratini et al. 2019). This study responds to the call as different roles for the public actor in industrial CE systems were identified and described in detail. The six roles above all highlight the diversity of the dimensions public agency can have: the same public actor can have different roles within the same system, or within the same system, there can exist several public actors with different roles. Therefore, public agency in CE should be considered as multi-dimensional phenomenon.

What are the relationship modes a public actor can have toward an industrial circular economy system? Currently, better exploration of the forms of collaboration and innovations among different CE actors is needed (Zucchella & Previtali 2019). The identified modes represent the nature of interaction a public actor can have toward/with an industrial CE system. The recognized two modes indicate that the roles of the public actor differ from each other based on the level (direct – indirect) and way (definitive – supportive) of involvement and engagement in the industrial CE system actions. Still, it cannot be stated whether one mode would be superior to another. However, the modes show that there seems to prevail two main ways to pursue CE, the so-called facilitative

and imperative approach. These approaches rather represent the two ends of a continuum than are dichotomous. On this scale, several emphases that are mixes of both facilitative and imperative approaches can occur. Also, the same public actor can have different modes in different roles or even within the same role.

Practical implications

For EIP administrators as well as practitioners developing collaboration in industrial CE systems, this study makes the public actor roles visible and this way may help the private actors to recognize new ways for mutual co-creation lowering the obstacles to public-private interaction. With a well-structured phenomenon it is easier for the managers to approach CE and plan how to develop new CE innovations with the contribution of a public actor. This way, new innovative CE systems can occur in a collaborative manner. Overall, all EIPs operate in public context, which is why it is valuable for any business to know the nuances of public agency, i.e. the laws of their operating environment.

For public authorities and policymakers, the study provides a structured view to public agency in industrial CE systems by discovering avenues and modes of interaction for public contribution in the systems. Through the recognized roles, the public actor can pursue sustainable actions in a facilitative or imperative manner. Moreover, the categorization table regarding the roles and modes of the public actor provides a library of actions and tools that public authorities can consider when planning their sustainability agendas. The explicitly stated public actor roles help public authorities to self-reflect their ways of interaction and ensure that the societal context for new CE business openings would be as supportive as possible.

Limitations

The presented research includes some limitations embedded in the chosen research methods. First, the roles and modes were recognized in a qualitative content analysis manner that is often a very iterative process involving redesigning, adjustments and revaluation (Schilling 2006). One way to enhance the general acceptability of the roles and modes would be a Delphi method.

The context of this paper allowed only a limited amount of cases to be studied. In qualitative studies, typically the focus is on a relatively small sample selected for a quite specific purpose. Moreover, studying information rich cases with theoretical sampling provides insights and in-depth understanding, but not empirical generalizations. (Patton 2015, p. 264) The sample of the reviewed cases being relatively moderate, there might still exist some relevant themes not covered in this study. The identified roles may not be all-inclusive, but they still show the broad spectrum of public roles in industrial CE systems.

Indeed, purposeful samples should be evaluated based on the purpose and rationale of the study (i.e. does the sampling strategy support the purpose of the study) rather than the sample size (Patton 2015, p. 311). As the aim was to broadly study the possible roles and modes of public agency, a deliberate choice was made to manually emphasize the Asian EIPs in the sample and have Chinese and European ideologies equally present among the cases. This is because these areas were considered representing the two major (opposite) public agency viewpoints. With different source material available and a different individual doing the study, different cases could have been selected.

The 20 international EIP cases were studied through the latest source material that is available on the Internet and can be deemed reliable with reasonable certainty. However, some of the material is over ten years old, meaning that the state of the EIP may have changed considerably since the release of the material. This does still not restrict this study as the aim was to examine a snapshot of public agency in each case. In other words, it is important to know what kind of forms of public agency have existed during a certain period of time. This is in line with qualitative content analysis that aims for creating a picture of a given phenomenon that is always contextual, not objective (White & Marsh 2006). This though means that no interpretations about the temporal incidence and development of public agency can be done on the basis of the cases.

Future research

This study does not try to present an all-inclusive theoretical background for public agency in CE systems. Instead, essential elements of public agency in industrial CE systems are expressed. The provided results serve therefore as a grounding for further research as they cover a variety of themes.

The field of CE and related agencies are ever-changing and developing, and a similar research with a bigger sample would enhance the generalizability of the results into a broader global context, from public agency in industrial CE systems toward public agency in CE in general. Similarly, a series of longitudinal studies made with up-to-date data would provide valuable insights of the temporal nature of public agency.

More studies are as well needed for further developing the findings of this paper: How the different roles of the public actor within the same EIP affect each other? What kind of practical effects do the modes facilitative and passive have, i.e. do they result in principle in different outcomes? Also, the continuum between facilitative and imperative modes could be complemented with the mode “passive” if further studies support this.

6 Acknowledgements

The data generation for this paper was supported by the European Regional Development Fund through the projects entitled “Future circular economy hubs in Finland” (CircHubs) (grant ID A72829) and “Utilization of side streams and masses of soil in the cities” (CircVol) (grant ID A74186) and the Strategic Research Council, Academy of Finland through the project entitled “Circular Economy Catalysts: From Innovation to Business Ecosystems” (CICAT2025) (grant ID 320194).

References

Antikainen, M., Aminoff, A., Kettunen, O., Sundqvist-Andberg, H. & Paloheimo, H. (2017). Circular Economy Business Model Innovation Process – Case Study, *Sustainable Design and Manufacturing 2017*, Vol. 68, pp. 546–555.

Ayres, L. & Knafl, K.A. (2012). Typological Analysis, in: Given, L.M. (ed.), *The SAGE Encyclopedia of Qualitative Research Methods*, SAGE Publications, Inc., Thousand Oaks, pp. 901–902.

Bellantuono, N., Carbonara, N. & Pontrandolfo, P. (2017). The organization of eco-industrial parks and their sustainable practices, *Journal of Cleaner Production*, Vol. 161, pp. 362–375.

Chinn, P.L. & Kramer, M.K. (1999). Theory and Nursing: A Systematic Approach, 5th ed., *Mosby Year Book*, St. Louis, 256 p.

Eisenhardt, K.M. & Graebner, M.E. (2007). Theory building from cases: Opportunities and challenges, *Academy of Management Journal*, Vol. 50(1), pp. 25–32.

Elabras Veiga, L.B. & Magrini, A. (2009). Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development, *Journal of Cleaner Production*, Vol. 17(7), pp. 653–661.

Erkman, S. & Van Hezik, C. (2016). Global assessment of eco-industrial parks in developing and emerging countries, *the United Nations Industrial Development Organization, Vienna International Centre*, Vienna, Austria, 24 p. Available: https://www.unido.org/sites/default/files/2017-02/2016_Unido_Global_Assessment_of_Eco-Industrial_Parks_in_Developing_Countries-Global_RECP_programme_0.pdf.

Fischer, A. & Pascucci, S. (2017). Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry, *Journal of Cleaner Production*, Vol. 155, pp. 17–32.

Fratini, C., Georg, S, & Jørgensen, M. (2019). Exploring circular economy imaginaries in European cities: A research agenda for the governance of urban sustainability transitions, *Journal of Cleaner Production*, Vol. 228, pp. 974–989.

Geng, Y., Liu, Z., Xue, B., Dong, H., Fujita, T. & Chiu, A. (2014). Emergy-based assessment on industrial symbiosis: a case of Shenyang Economic and Technological Development Zone, *Environmental Science and Pollution Research*, Vol. 21(23), pp. 13572– 13587.

Geng, Y., Xinbei, W., Qinghua, Z. & Hengxin, Z. (2010). Regional initiatives on promoting cleaner production in China: a case of Liaoning, *Journal of Cleaner Production*, Vol. 18(15), pp. 1502–1508.

Ghisellini, P., Cialani, C. & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, Vol. 114, pp. 11–32.

Gibbs, D. & Deutz, P. (2007). Reflections on implementing industrial ecology through eco-industrial park development, *Journal of Cleaner Production*, Vol. 15(17), pp. 1683–1695.

Harris, S. (2007). Industrial Symbiosis in the Kwinana Industrial Area (Western Australia), *Measurement and Control*, Vol. 40(8), pp. 239–244.

Herczeg, G., Akkerman, R. & Hauschild, M.Z. (2018). Supply chain collaboration in industrial symbiosis networks, *Journal of Cleaner Production*, Vol. 171, pp. 1058–1067.

Isaksson, K. & Heikkinen, S. (2018). Sustainability Transitions at the Frontline. Lock-in and Potential for Change in the Local Planning Arena. *Sustainability*, Vol. 10(840).

Jacobsen, N.B. (2006). Industrial Symbiosis in Kalundborg, Denmark: A Quantitative Assessment of Economic and Environmental Aspects, *Journal of Industrial Ecology*, Vol. 10(1), pp. 239–255.

Kalundborg Symbiosis. (2019). Kalundborg Symbiosis, web page. Available (accessed 16.2.2019): http://www.symbiosis.dk/en/.

Kluge, S. (2000). Empirically Grounded Construction of Types and Typologies in Qualitative Social Research, *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, Vol. 1(1).

Korhonen, J. (2001). Four ecosystem principles for an industrial ecosystem, *Journal of Cleaner Production*, Vol. 9(3), pp. 253–259.

Korhonen, J. (2005). Theory of industrial ecology: the case of the concept of diversity, *Progress in Industrial Ecology, An International Journal*, Vol. 2(1), pp. 35–72.

Liu, Z., Adams, M., Cote, R.P., Geng, Y. & Li, Y. (2018). Comparative study on the pathways of industrial parks towards sustainable development between China and Canada, *Resources, Conservation and Recycling*, Vol. 128, pp. 417–425.

Liwarska-Bizukojc, E., Bizukojc, M., Marcinkowski, A. & Doniec, A. (2009). The conceptual model of an eco-industrial park based upon ecological relationships, *Journal of Cleaner Production*, Vol. 17(8), pp. 732–741.

McDowall, W., Geng, Y.-J., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., Kemp, R. & Doménech, T. (2017). Circular Economy Policies in China and Europe, *Journal of Industrial Ecology*, Vol. 21(3), pp. 651–661.

Morikawa, M. (2000). Eco-Industrial Developments in Japan, Indigo Development Working Paper #11, *RPP International*, Indigo Development Center, Emeryville, California, USA.

Mulrow, J.S., Derrible, S., Ashton, W.S. & Chopra, S.S. (2017). Industrial Symbiosis at the Facility Scale, *Journal of Industrial Ecology*, Vol. 21(3), pp. 559–571.

Paquin, R.L. & Howard-Grenville, J. (2013). Blind Dates and Arranged Marriages: Longitudinal Processes of Network Orchestration, *Organization Studies*, Vol. 34(11), pp. 1623–1653.

Park, H.-S. & Won, J.-Y. (2007). Ulsan Eco-industrial Park: Challenges and Opportunities, *Journal of Industrial Ecology*, Vol. 11(3), pp. 11–13.

Patala, S., Hämäläinen, S., Jalkala, A. & Pesonen, H.-L. (2014). Towards a broader perspective on the forms of eco-industrial networks, *Journal of Cleaner Production*, Vol. 82, pp. 166–178.

Patton, M.Q. (2015). Qualitative research & evaluation methods: integrating theory and practice, 4th ed., *SAGE*, Los Angeles, USA, 806 p.

Robson, C. (1994). Real world research: a resource for social scientists and practitioner researchers, Repr ed., *Blackwell*, Oxford, 510 p.

Schilling, J. (2006). On the Pragmatics of Qualitative Assessment: Designing the Process for Content Analysis, *European Journal of Psychological Assessment*, Vol. 22(1), pp. 28– 37.

Urbinati, A., Chiaroni, D. & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models, *Journal of Cleaner Production*, Vol. 168, pp. 487–498.

Valentino, A. (2015). Eco-industrial parks: the international state of art, in Caroli, M., Cavallo, M. & Valentino, A. (ed.), *Eco-Industrial Parks: A Green and Place Marketing Approach*, Luiss University Press, Rome, pp. 21–42.

Van Berkel, R., Fujita, T., Hashimoto, S. & Fujii, M. (2009). Quantitative Assessment of Urban and Industrial Symbiosis in Kawasaki, Japan, *Environmental Science and Technology*, Vol. 43(5), pp. 1271–1281.

Velenturf, A.P.M. (2017). Initiating resource partnerships for industrial symbiosis, *Regional Studies, Regional Science*, Vol. 4(1), pp. 117–124.

Veleva, V., Todorova, S., Lowitt, P., Angus, N. & Neely, D. (2015). Understanding and addressing business needs and sustainability challenges: lessons from Devens eco-industrial park, *Journal of Cleaner Production*, Vol. 87, pp. 375–384.

Walls, J.L. & Paquin, R.L. (2015). Organizational Perspectives of Industrial Symbiosis: A Review and Synthesis, *Organization & Environment*, Vol. 28(1), pp. 32–53.

Wang, Q., Deutz, P. & Chen, Y. (2017). Building institutional capacity for industrial symbiosis development: A case study of an industrial symbiosis coordination network in China, *Journal of Cleaner Production*, Vol. 142, pp. 1571–1582.

White, M.D. & Marsh, E.E. (2006). Content Analysis: A Flexible Methodology, *Library Trends*, Vol. 55(1), pp. 36–45.

Yang, S. & Feng, N. (2008). A case study of industrial symbiosis: Nanning Sugar Co., Ltd. in China, *Resources, Conservation and Recycling*, Vol. 52(5), pp. 813–820.

Yin, R.K. (2009). Case study research: design and methods, 4th ed., *Sage Publications*, Thousand Oaks (Calif.), USA, 219 p.

Yu, C., de Jong, M. & Dijkema, G.P.J. (2014). Process analysis of eco-industrial park development – the case of Tianjin, China, *Journal of Cleaner Production*, Vol. 64, pp. 464–477.

Yu, C., Dijkema, G.P.J. & de Jong, M. (2015a). What Makes Eco-Transformation of Industrial Parks Take Off in China?, *Journal of Industrial Ecology*, Vol. 19(3), pp. 441–456.

Yu, C., Dijkema, G.P.J., de Jong, M. & Shi, H. (2015c). From an eco-industrial park towards an eco-city: a case study in Suzhou, China, *Journal of Cleaner Production*, Vol. 102, pp. 264–274.

Yu, F., Han, F. & Cui, Z. (2015b). Evolution of industrial symbiosis in an eco-industrial park in China, *Journal of Cleaner Production*, Vol. 87, pp. 339–347.

Zeng, H., Chen, X., Xiao, X. & Zhou, Z. (2017). Institutional pressures, sustainable supply chain management, and circular economy capability: Empirical evidence from Chinese eco-industrial park firms, *Journal of Cleaner Production*, Vol. 155, pp. 54–65.

Zhu, Q., Lowe, E.A., Wei, Y.-a. & Barnes, D. (2007). Industrial Symbiosis in China: A Case Study of the Guitang Group, *Journal of Industrial Ecology*, Vol. 11(1), pp. 31–42.

Zucchella, A. & Previtali, P. (2019). Circular business models for sustainable development: A "waste is food" restorative ecosystem, *Business Strategy and the Environment*, Vol. 28(2), pp. 274–285.