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THE PROCESS OF BUILDING INTER-ORGANIZATIONAL COLLABORATION FOR INDUSTRIAL SYMBIOSIS

Two cases from Finland: ECO3 & Envitech

Master's Thesis
Faculty of Engineering and Natural Sciences
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October 2020

ABSTRACT

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Master of Science Thesis
Tampere University
Master's Degree Programme in Industrial Engineering and Management
October 2020

The present situation of environmental degradation and natural resource depletion encouraged researchers to find new ways of integrating sustainability in industrial activities. The concept of industrial symbiosis (IS) has the potential to fight these challenges by creating linkages among co-located industrial actors. In this system, the waste of one actor is considered a resource for another, and share common utilities for operations. The concept has been practically implemented in many countries to introduce resource-efficient operations. Therefore, this research aims to identify the collaboration process development toward the IS system while mapping the ecosystem actors and diverse driving or inhibiting factors.

To seek answers for the research questions, a qualitative multiple case study analysis on two nationally significant IS cases from Finland was conducted. The primary data sources for both of the case studies were direct interviews with the specified ecosystem actors. The interview data were transcribed, systematically grouped, and analyzed by following the research theme. The secondary data were multi-sourced from company webpages, thesis, reports, book chapter, and authenticity of some secondary data were double-checked during the interviews. Data-driven thematic analysis was implemented to group the researched data on each case, with the identification of critical incidents during the IS evolution phases, followed by an ecosystem actor mapping through Kumu software and outlining the factors impacting the IS system. Lastly, a case comparison by defining dimensions under the researched themes was performed to define the distinctive pattern of both cases.

The key findings indicate that organization of the IS system can be categorized as a "publicly driven" or "company driven" model. Nevertheless, both models encompass the emergence, probation, and development & expansion phases of the IS evolution process with diverse activities organized by the ecosystem actors. A publicly driven IS model is mainly inaugurated by the local governments and the process advances as a planned symbiosis model. The company driven IS model mainly progresses through the spontaneous participation of local company actors based on their own need. The publicly driven IS model functions through a central operator while the individual company actors are the key decision taker of the company driven model without any centralized approach. The organization of activities in both cases is impacted by a similar set of driving or inhibiting factors like legislation, location, changes in people's attitudes, and the main driving element is a human actor.

This study contributes to the existing knowledge of IS process development by looking into critical cases from processual dimensions. The investigator suggests that the successful evolution of an IS system will require active collaboration and co-operation from public organizations and private company actors. A co-operative mindset among all the stakeholders can be established by developing a shared vision and will require a platform company to centrally organize the IS system development. The company actors need to be more open, while a change in attitude and new legislation is highly required to encourage bio and circular economy businesses through IS.

Keywords: Industrial symbiosis, IS ecosystem, driver or inhibitor, public-private collaboration.

PREFACE

The journey of my Master's thesis writing started with a mixed feeling of excitement and worries at the same time. It made me happy that I got the opportunity to research in a study field that interests me and has driven me to keep digging deeper to generate broader. As I believe, the circular economy is the most prominent and logical way of fighting global challenges and introducing sustainability in business operations.

Although I was excited about the empirical case studies, yet the literature review part sunk me in a pool of information at the beginning that made me confused about which direction to drive. Nevertheless, I got the privilege of most amazing supervisors Leena and Jarmo, who guided me in every aspect and made me realize the value of my hard work. I must acknowledge that the motivating and encouraging words from my supervisors functioned as fuel to drive me till the end of this journey. Alongside this, I would like to thank my colleagues in the CITER team, for being supportive and insightful comments during research seminars. I would also like to thank all the interviewed actors for their co-operation and providing such insightful information that resulted in developing such a strong case study.

Finally, I would like to thank my mother, who believed in me in every step of my life which made it possible to come this far in my life. Not to forget about my husband, who tried to give me every comfort and support to make this stressful journey smoother, by tolerating all my tantrums. I feel really blessed to have such people surrounding me which made my journey in a new country, new environment a lot easier. I believe this entire process taught and encouraged me a lot that will drive me to attain my life goals.

Tampere, 28 October 2020

Puja Saha

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LIST OF SYMBOLS AND ABBREVIATIONS

IE	Industrial ecology
IS	Industrial symbiosis
CE	Circular economy
EIP	Eco-industrial park
TUNI	Tampere Universities
CITER	Center for Innovation and Technology Research

1. INTRODUCTION

1.1 Background

The traditional industrial processes follow an open-end operating approach where raw materials derived from natural resources are converted into a fraction of products and by-products. In most cases, these industrial by-products are categorized as wastes, and if left untreated can significantly damage the environment nearby. The massive deduction of natural resources for industrial activities not only degrade the environmental condition but also deploys the availability of raw materials for further production processes (Lehtoranta *et al.*, 2011). Hence, the issue of environmental degradation raised awareness among industrials only when they realized the significant depletion of non-renewable resources in the form of materials and energy (Boons and Baas, 1997). Along with industrial operators, academics, and policymakers are also highly concerned about these environmental issues due to high resource consumption (Geissdoerfer *et al.*, 2017) that need to be solved by integrating a sustainability approach toward industrial operations (Frosch and Gallopoulos, 1989). Nevertheless, the creation of a balance between industrial activities and environmental management requires experimenting and designing new ways of leading industrial activities (Ehrenfeld and Gertler, 1997).

Besides this massive amount of waste produced by households or industries came into consideration of proper treatment because of the scarcity of landfill space and to diminish environmental pollution (Roberts, 2004). As per an estimate, approximately 2.01 billion metric tonnes of solid wastes are generated through different activities all around the world which is estimated to rise to 3.04 billion metric tonnes by 2050 (WasteDive, 2018). Hence, Pan, et al. (2015) suggested that the waste can be converted into an energy source, which will reduce the emission of greenhouse gases, and will consequently cut the use of natural resources. However, at present only 13.5% of the waste is utilized for recycling purposes and 5.5% of which are further composted (WasteDive, 2018). In such a scenario, practitioners, policymakers, business consultants emphasized the concept of circular economy (CE) to be implicated by industrial actors in their daily operations to decline the environmental damages (Geissdoerfer *et al.*, 2017). Besides, the European Union (EU) has introduced “circular economy” as a strategy to bring environmental sustainability in production and consumption methods (Saavedra *et al.*, 2018; Jarre *et al.*,

2020). Supporting the strategy of the EU, the national government of Norway, Denmark, Sweden, Finland, China, Canada, Japan already initiated CE activities at different levels (Korhonen, Honkasalo and Seppälä, 2018). Ellen MacArthur Foundation (2020) advised company actors to operate following CE principles as it will gain economic benefit with ensurance of environmental and economic sustainability.

The main principle of CE is defined as “closing resource loops” through the circulation of materials and nutrients into the biosphere (Murrari et. al., 2015). CE application resolves the scarcity of natural resources, currently faced by many industries with consideration of minimizing environmental degradation (Pan, et al., 2015). While CE has been a recent trend predominantly implicated by policymakers toward solving the environmental challenges through a cyclical flow of materials (Korhonen, Honkasalo and Seppälä, 2018); a long-ago academics mentioned the concept of industrial ecology (IE) as a way to control the environmental degradation that happens through industrial activities and introduce a sense of sustainability in economic activities (Ehrenfeld, 1997; Lambert and Boons, 2002). Here, the term “ecology” symbolizes how industrial systems should be designed and organized by replicating the natural ecosystem approach. Nevertheless, the goals of IE are highly aligned to circular economy principles (Nakajima, 2000; Pakarinen *et al.*, 2010). The activities planned in an industrial ecosystem are focused on minimizing the amount of waste generated and further renewal of the effluents into resources (Roberts, 2004).

Even though the IE approach can be implicated by single industrial actors, yet the most important are the ones implemented at the local level as the destructive human action initiates from this level (Graymore, Sipe and Rickson, 2008). The local level IE implication approaches with consideration of the society and all the industrial operators within it and how they operate to conserve natural resources. This local-level implication of IE principles is broadly known as Industrial Symbiosis (IS) (Desrochers, 2004). In an IS, the industrial processes are designed in a way that no material nor energy will leave the system boundary (Lowe, 1993). Besides, the notion of IS encompasses the three key aspects of sustainability: society, economy, and environment, widely recognized as the “triple bottom line” (Herczeg, Akkerman and Hauschild, 2018). The industrial actors attain economic benefits through sharing resources and joint operations. This efficient way of resource utilization can aid the economic performance of an organization (Ehrenfeld and Gertler, 1997). The society achieves a part of the value with the creation of new employment opportunities and upgrading the regional economy (Boons, Spekkink and Jiao, 2014), and finally, the environmental benefits are the most realized ones as IS encourage reduced use of virgin materials, closed-loop material cycle and lowering the

emission of CO_2. The above-mentioned perspectives indicate IS is an excellent way of bringing economic and environmental sustainability in a locality, therefore this study prioritizes to analyze the organizational process of IS systems.

The IS concept structured in the form of an eco-industrial park (EIP) (Zhang, Zheng and Fath, 2015) is emphasized to be studied further as those are exceptionally important for development activities in recent days. EIPs are established in a certain region allowing to monitor the CE implementation and control of environmental damages (Gómez, et al., 2017). EIPs are defined as a community of co-located business actors sharing resources to operate (Lombardi and Laybourn, 2012), in co-operation with the local community to ensure environmental sustainability. Literature suggests that attaining the goals of environmental sustainability requires a collaborative approach from multiple stakeholders like academia, industrial actors, and the governmental authorities (Ingstrup, Aarikka-Stenroos and Adlin, 2020). Besides, ecological deformations are the result of actions implied by a network of industrials that is difficult to eradicate by the individual level-firms only (Patala *et al.*, 2014). Therefore, it requires the incorporation of an ecosystem approach to reviewing the possible role of different stakeholders to bring environmental sustainability. For instance, the governmental agencies are responsible to formulate the waste management policies, that needs to be practiced by company actors. An EIP incorporates all these different kinds of actors, thus considered as a collaborative approach of eradicating environmental problems in an economical way (Heeres, Vermeulen and De Walle, 2004). This study looks into the structure of EIP from an ecosystem perspective with the contemplation of IS from a processual approach to understand the EIP system organization.

Furthermore, organizing collaborations to initiate CE activities through IS settings is greatly catalyzed or inhibited by many factors already existing and emerging throughout the process (Mathews and Tan, 2011; Sakr *et al.*, 2011). These factors can be related to the technical or economical dimensions that are perceived by the actors directly operating in the system, or even can emerge from the social and institutional setting where the system has been initiated (Yu, De Jong and Dijkema, 2014; de Jesus and Mendonça, 2018). The catalyzing factors which bring positive changes in the IS development are considered as drivers, while the challenging factors are recognized as inhibitors that slow down the activities, and need to be considered during the development process. Hence, this study aims to accomplish the research gap as acknowledged by penetrating through multiple research streams. *Research still lacks the identification of efficacious organization process of an IS network, as some researchers proclaimed the spontaneous (Boons, Spekkink and Mouzakitis, 2011) way of collaboration as the most successful ones whilst*

others argued collaborations initiated through a third party (Paquin and Howard-grenville, 2012) can result in attaining ultimate benefits creating a contradictory viewpoint. The IS literature broadly focuses on the opportunity of material sharing without much consideration of how the ecosystem is organized (Pakarinen *et al.*, 2010), the stakeholders or actors involved in the system, and extensively lacking the management perspective of the broad network. Following all the mentioned aspects, this research investigates the process development of IS systems with the identification of diverse ecosystem actors and the driving or inhibiting factors impacting the organizational activities.

1.2 Aim and scope of the research

The concept of IS has grown increased attention among global actors as a way to fight environmental challenges. The EU addressed the strategy of circulating waste or by-products into the economy through collaborating industries in a symbiotic relationship (Moodie, Salenius and Leino, 2019). By following the directive of the EU, Finland has planned several bio and circular economy projects around IS in multiple industrial cities (FISS, 2020). The formation of an IS structure requires creating inter-linkage among multiple actors from diverse industrial fields (Bai *et al.*, 2014). These multiple actor systems need to function as a single business entity with the formation of a business ecosystem (Lowe and Evans, 1995). However, the number of symbiotic arrangements moving toward the development phases and reaching the end goals is unexpectedly lesser.

As Finland initiated numerous IS set-ups at the regional level providing an opportunity to study those cases in detail to recognize the kind of actors present in the ecosystem, what are the main roles played by those actors in the initiation phases. Additionally, the symbiotic network progress through a set of actions caused by the actors involved in the system which leads to the importance of identifying those critical incidents that result in the emergence and development of the ecosystem (Boons, Spekkink and Jiao, 2014). In Finland, majority of the IS arrangements are still in the planning phases, for example in the Pirkanmaa region there are some well-recognized symbiosis cases in Hiedanranta, ECO3, Tarastejärvi. Investigating the actual emergence pattern, potential roles played by key actors involved can lead to generating valuable knowledge that can contribute to the development of Finnish IS systems.

The purpose of this research is to get a pragmatic view on how the collaboration process advances towards the creation of an IS structure over time and what are the effects of diverse driving or inhibiting factors in this ecosystem evolution process. As IS systems are organized in collaboration of actors from public and private sectors, are more important for the Finnish national level CE and IS approach, this research predominantly

focuses on analyzing IS cases that incorporate both public and private actors. Initiating public-private collaboration level includes significant challenges inhibiting the growth of the platform or might include facts that drive the development of environmental sustainability. The drivers and inhibitors identified in the cases are primarily divided into two categories: soft and hard factors and distributed into five subthemes like institutional, social, environmental, economical, and technical (de Jesus and Mendonça, 2018).

The above-mentioned research objectives resulted in guiding the construction of three key research questions to be investigated. First, to understand the evolution process of an IS system the study tries to identify what critical incidents or events result in developing the platform. Next, the study aspires to recognize how the collaboration is organized in actual settings with the key actors defined and what are the main incentives for them to join the collaboration. Lastly, the study scrutinizes the driving and inhibiting factors for the development of a collaboration platform. In this aspect, the study defines the facts that drive the IS system development and the points that driven or inhibited company actors to join the symbiosis platform. The main research questions are designed as follows:

- RQ1: How does the collaboration process for the industrial symbiosis systems emerge and develop?
- RQ2: How is the industrial symbiosis ecosystem organized?
- RQ3: What are the main driving or inhibiting factors impacting organization of the industrial symbiosis systems?

In order to pursue an answer to the above-mentioned questions, the structure of the research was confined to a multiple case study method (Baxter and Jack, 2008) with a processual approach (Pettigrew, 1997) toward the case analysis. The case selection was framed by focusing on the priorities followed by a selection of extreme cases (Patton, 2003). This particular research focused on picking IS cases that contributed to Finland's national-level development, with extremity in nature to visualize comprehensive pragmatic dimensions of the cases. The processual approach of case analysis facilitates defining the core phenomenon of organizing an IS system, with the revelation of underlying core actors in the IS system (Boons, Spekkink and Jiao, 2014). Thus, investigating the answers to those research questions will assist in highlighting the process of Finnish IS ecosystems and actualizing the drivers or inhibitors spawned during the process.

To imply the IS concept at a practical level numerous symbiotic structure has been organized in the form of an EIP initiated by public organizations or even by private company actors according to their need (Tudor, Adam and Bates, 2007). Yet, the structure of the

symbiotic ecosystem differs to a large extent based on the country of initiation (Costa, Massard and Agarwal, 2010). However, this research is limited to studying only IS cases originated in Finland, to get a comprehensive view of the current status, and recognize the future area to be developed. Yet, the multiple case study as a research approach has broadened the scope of analyzing two different Finnish IS systems. The actualized data from the cases will not only contribute to understanding the evolution process of an IS rather it will probe the opportunity of comparison to perceive the successive elements from both cases.

Furthermore, the processual approach will identify the key actors present in the ecosystem and how their role has evolved over the period to organize the collaboration (Boons, Spekkink and Jiao, 2014). Finland initiated a substantial number of IS arrangements in different cities to be a forerunner of fighting environmental challenges in Europe (FISS, 2020). Thus, the identified success factors from the studied cases can be practically implied to other region's IS process advancements. The research data will also guide the national level policymakers or economic development platforms to formulate strategies on what needs to be done at present for the advancement of Finnish IS systems.

The concept of IS has emerged to replicate the natural ecosystem approach in industrial activities with the co-evolution of actors from different fields (Ehrenfeld and Gertler, 1997). Thus, analyzing the *ecosystem of IS* is one of the prime concerns of this research. Due to the very nature of an IS process development, the ecosystem comprises of multiple actors (Bain *et al.*, 2010). In that context, the researched ecosystem will be a multi-actor ecosystem. Organization and management of such a large network of actors possess significant challenges and can be researched from a wide spectrum of dimensions such as mode of interactions, relationships among actors involved. In order to meet the predetermined objectives, this research will primarily focus on identifying the key actors of the ecosystem and interviewing those actors to understand their motives to join the IS platform. Alongside this, research will investigate the role of different organizational clusters from diverse institutional settings in the development of the IS ecosystem. The ecosystem research approach provides the opportunity of investigating network boundary and ecosystem composition (Aarikka-stenroos and Ritala, 2017).

This research work has been accomplished as a Master’s thesis study at Tampere University with the purpose of contributing to the CircVol, UPCE, and CICAT2025 project. The objective of CircVol project is to investigate material flow and business potential through CE hubs where the UPCE project focuses on collaborative platforms to organize CE activities and finally, the CICAT2025 project aims to identify the catalyzing factors

impacting multi-actor CE ecosystems. However, this research does not focus on analyzing CE activities particularly rather it mainly investigates the organization and management of CE initiatives in the form of a large network or IS ecosystem. The IS system activities are organized with multi-actor ecosystem settings who collaboratively approach by following the principle of CE which contributes to CircVol and UPCE project objectives. Furthermore, this research also aims to identify the driving and inhibiting factors impacting the organization of IS process activities which will meet the CICAT 2025 project objective.

1.3 Research structure

The first chapter of this Masters's thesis study introduces the background and purpose of studying industrial symbiosis, by highlighting the growing trend of CE and how IS systems can be an efficient way of establishing CE practices globally. Therefore, the background literature provides a brief view of IS, sustainability, and CE practices. Later, the research objectives with the key research questions have been described, along with the scope and structure of the study. With a preliminary overview of research objectives, a literature review is performed on the most relevant topics to develop a concrete theoretical understanding.

The theoretical background is presented in two chapters: Chapter 2 and Chapter 3. The first theory chapter is primarily focused on understanding the evolution of IS concept, therefore section 2.1 broadly discusses IE and its principles, as the concept of IS has emerged from IE. Afterward, section 2.2 extensively discusses IS literature by defining the IS and categorization of IS models. The third chapter is concerned with assimilating the organization process of the IS systems. Therefore, section 3.1 provides a literature review on the emergence process of IS systems from the processual dimension. Hence, section 3.2 initiates with a short overview of the ecosystem literature stream, which further indicates why the ecosystem approach is appropriate to investigate the IS process. Next, section 3.3 outlines different soft and hard factors that are associated with an IS system and impacting different activities indirectly or directly. To summarize the knowledge from literature a theoretical framework has been synthesized in section 3.4 to comprehend the collaboration process development toward IS with an overview of the level of ecosystem actors and diverse factors impacting the process.

The theoretical chapters are followed by research methodology in Chapter 4. For empirical analysis a qualitative multiple case study method chosen, the rationale behind choosing this method is also described. Thereafter, a justification for case selection and prioritized aspects of selected cases were discussed. Next, the data collection method

and diverse data sources, and interviewed ecosystem actors for the studied cases were presented in the form of a table. Additionally, on an overview of secondary data sources like company websites, blog posts, documents were also summarized. The last section of this chapter discusses the chosen data analysis method like data-driven thematic analysis, critical incidents, ecosystem mapping technique, and comparative analysis of cases in detail.

The analysis from empirical case studies is presented in Chapter 5 named Results. A systematic approach in accordance with the research questions was followed to structure the results from the case analysis. First, an introductory concept on the selected IS cases were presented for both cases, which was followed by the IS emergence process analysis, as an answer of RQ1; the IS ecosystem actor analysis, indicating an answer to RQ2; and the driving and inhibiting factors impacting the IS system, addressing to RQ3. Following that, a comparative analysis on both of the studied IS systems were outlined in Chapter 6. The comparative study was conducted under the above mention three key research themes by defining different dimensions. Lastly, Chapter 7 summarizes and discusses the actualized key findings from the empirical case studies, compare it to the synthesized theoretical framework, further the theory contribution and practical implications for researchers, managers have been outlined and finally, future research agenda on IS systems have been provided, chapter concluding with references and appendix.

2. UNDERSTANDING INDUSTRIAL SYMBIOSIS

This chapter introduces the key concepts related to the industrial symbiosis (IS) approach. The chapter begins with defining the concept of industrial ecology (IE) by highlighting the principles of IE. Following that the chapter provides an overview of how IE principles are implicated at a practical level in the form of IS and further discusses the categorization of different IS models based on the emergence process.

2.1 Industrial ecology principles

Industrial activities are an essential part of any nation since it is the main source of economic development. Different industrial processes deliver necessary materials or services for everyday use while creating employment opportunities at the same time to conduct those activities. Although industries are the source of development of any society, the different industrial manufacturing process results in damaging the environment to a great extent (Geissdoerfer *et al.*, 2017). Therefore, it requires creating a balance between industrial activities and environmental degradation (O'rourke, Connelly and Koshland, 1996). Researches indicated the "industrial ecology" approach as a way to fight this dilemma (Erkman, 1997). Furthermore, the IE concept is not only confined to diminishing environmental damages but also an answer to the present challenges of resource depletion faced by industrials.

In academic literature, numerous definitions and principles of IE have been outlined. Some literature recognized IE as a particular process (Roberts, 2004), while some claimed IE as more of a model (Li, 2018) to bring environmental sustainability. Over the years IE gradually evolved into an "interdisciplinary" study field (Ehrenfeld, 2004; Li, 2018) which focuses on reducing the amount of wastes generated by the man-made industrial ecosystem by replicating the natural ecology approach (Pakarinen et al., 2010). O'rourke, Connelly, and Koshland (1996) mentioned IE as a strategy to reform the organizational structure toward sustainability and will set a vision to drive leaders from public institutions and business actors. The different research perspectives on IE mentioned by authors have made the study field rather scattered without any concrete theory to implicate at a practical level. Regardless, IE provides a conceptual holistic framework of redesigning the current industrial processes in a way that will lessen environmental damages (Tibbs, 1992; Ehrenfeld, 1997; Erkman, 1997). The idea is that industrial actors can bring a radical change in their current operating process by implicating the natural

ecosystem approach or can involve the approach as an extension to their present model. Yet, the practical implications of the IE system are still in the elusive phase (Gibbs and Deutz, 2005).

The term “industrial ecology” itself embodies two perspectives: industry and ecology approach (Ayres and Ayres, 2002). According to the IE theory, industrials are considered as key actors (Ayres and Ayres, 2002) to lessen the environmental damages by following the natural ecosystem approach in the product manufacturing phases (Gibbs and Deutz, 2005). In the natural ecosystem, every material flow in a circular way the only source of energy is sunlight, thus the target of industrial ecology is to convert the current linear flow of industrial materials into a cyclical order to decrease the amount of natural resource consumption (Leigh and Li, 2014). The idea behind IE is to replicate the natural ecosystem at every phase of industrial activities. Boons and Baas (1997) specified the features of natural ecosystem to be mimicked in industrial activities. The first focus is to reduce the amount of energy consumed by industrial processes and the amount of waste produced. Next, the industrial system needs to prioritize lessened use of scarce resources rather than utilize the waste generated as an input for different processes. Finally, the industrial ecosystem should be resilient in nature to absorb unwanted risks. Thus, the organization of IE system generates the idea of considering industries and processes as an integrated model (Gibbs and Deutz, 2005) with the co-ordination of industrial actors from diverse fields (Boons and Baas, 1997).

Frosch and Gallopoulos (1989) also referred to IE as an integrated model of transforming the traditional industrial model into a resource (material and energy) efficient model. Similar to that Ehrenfeld (1997) suggested the focus area of industrial ecology is converting the linear material flow of industrial systems into a circular way. Allenby (1992) and Lowe (1993) consider IE as the gateway to maintain sustainability by creating a connection between biological and physical systems. Gibbs and Deutz (2005) proposed that in an industrial ecosystem all the activities and organizations need to work in a synchronized way to utilize the resources in a cycle by reducing the amount of waste generated. Besides, different industrial operations release a significant amount of heat as which can be utilized as a source of energy by sharing with adjacent firms (Frosch and Gallopoulos, 1989). Industrial ecology opens the boundary of industrial processes to integrate as a system different, yet it's necessary to define the extent of the boundary. The application principle of industrial ecology is illustrated in Figure 1.

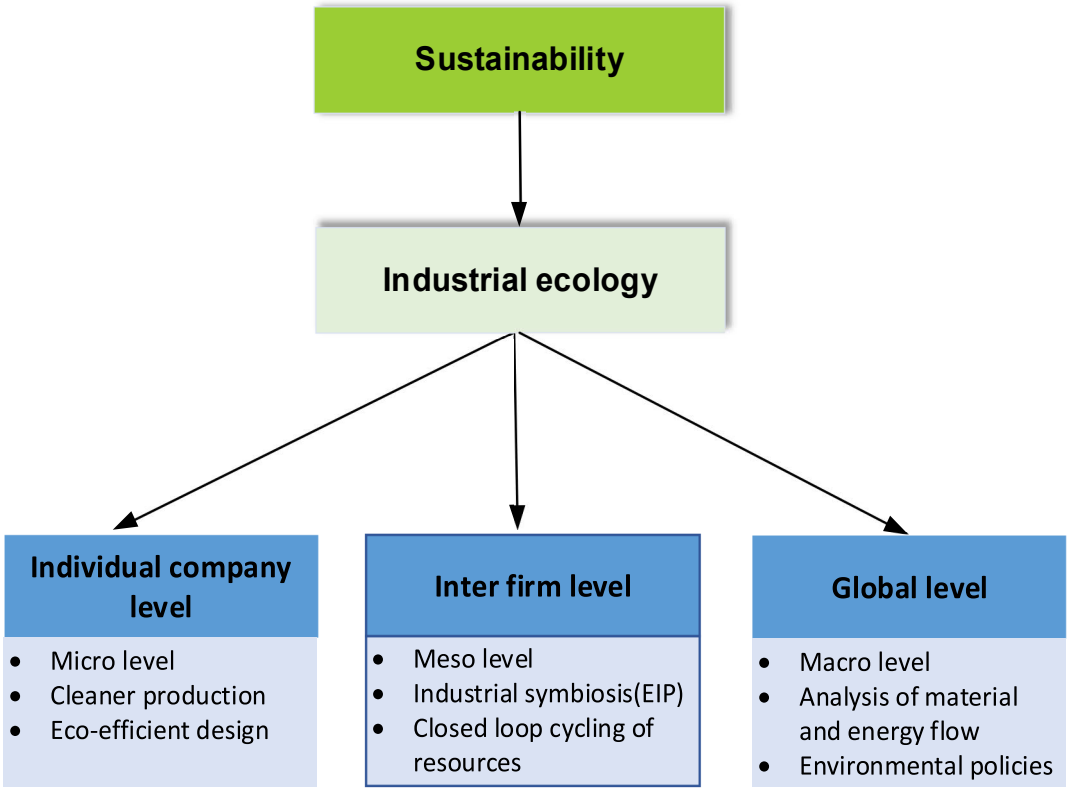

Figure 1. *Operative level of industrial ecology (Ayres and Ayres, 2002).*

Application of the IE principles can be segmented into three-level: individual firm level, inter-firm level, and regional/global level (Ayres and Ayres, 2002; Roberts, 2004; Clift and Druckman, 2015). Individual firm-level application is recognized as micro-level, where companies focus on integrating sustainability thinking in their business operations (Taddeo, Simboli and Morgante, 2012). At this level, firms can integrate an eco-efficient design perspective from the beginning of manufacturing process plans (Ayres and Ayres, 2002). Firms include technological intelligence to maximize the output from a single resource and most of the technological innovation for waste minimization takes place at this micro-level (Ayres and Ayres, 2002; Clift and Druckman, 2015). This approach will help companies to create a green image among customers and suppliers. Next, at the inter-firm level, IE is organized in the form of IS (Yeo, *et al.*, 2019). In an IS system, the main concern remains on the efficiency achieved through the collaboration of industrial actors (Roberts, 2004). Analyzing the IS process is the main concern of this research and it has been highlighted in figure 1 with a blue box. Therefore, the IS concept has been studied broadly in the later parts of this research. The regional or global level IE implications are more focused on budget (Taddeo, Simboli and Morgante, 2012) and

investigate the mass flow of material and energy (Ayres and Ayres, 2002). It also incorporates thinking like decarbonization which will assist the development of environmental policies (Clift and Druckman, 2015).

A number of IE principles have been defined to understand the distinctive nature of organizing industrial activities in the form of an industrial ecosystem. The defining principle of an industrial ecosystem is that the closely located organizations will share sidestreams, energy, and waste (Ehrenfeld and Gertler, 1997) which is specifically followed at inter-firm level IE application (Roberts, 2004). Korhonen (2001) analyzed the principle of the natural ecosystem to be implicated in the industrial ecosystem. Korhonen (2001) mentioned the term “round put” to indicate the circular flow of materials in the ecosystem. Industries are dependent on natural resources for economic development, which is deploying. Therefore, industries need to concentrate to identify ways for recycling the materials, cascade energy from the process, and utilize renewable sources of energy production. An industrial ecosystem provides necessary infrastructures to connect industries and enhance relationships fostering opportunities for industrials with local communities and the government to progress with sustainable business practices (Roberts, 2004). Converting an industrial system to an ecosystem requires the involvement of “diverse” actors to survive for the long term (Korhonen, 2001). Even in the natural ecosystem, many different species create a circle by sharing energy or resources for survival. A diverse species is included in the network as they function in a chain. In industrial settings variety of processes exists, however, diversity in co-operation is stated as a principle for industrial ecology (Korhonen, 2001). The actors involved in the ecosystem can co-operate in diverse ways according to its organizations operating principle or can be based on a resource sharing method, or any specific need. Nevertheless, the industries need to be strategically aligned, by clustering the firms together with the probability of maximum value creation through an exchange of by-products (Roberts, 2004). In must be noted that the ecosystem also needs to have the capability of adjusting with the “local” operating environment and conditions (Korhonen, 2001).

Furthermore, network development engages numerous actors in a relationship that need to collaboratively face the limiting factors emerging in the operating environment. For example, the actors should jointly focus on technological innovation to fight the scarcity of natural resources. The ecosystem should provide necessary facilities or tools that will catalyze relationship creation opportunities, encourage technological advancement that will support the clean production method (Roberts, 2004). Lastly, “change” in an ecosystem is a common phenomenon (Korhonen, 2001). Change in the industrial ecology per-

spective indicates lessening the dependency on non-renewable resources. Thus, industrial ecology principles can introduce a sustainable model of business operation cutting down the dependency on virgin materials. In addition to that application of IE principles will scale down the amount of waste produced enormously while securing the source of constant material flows (Ehrenfeld and Gertler, 1997). As this research particularly focuses on studying industrial ecosystems approach implicated at the inter-firm level, the later sections will discuss those largely.

2.2 Defining industrial symbiosis

The study field of "Industrial Symbiosis" (IS) emerged from the application of industrial ecology principles. The industrial ecology concept focuses on minimizing the amount of waste produced which requires identification of the source of waste production and then thinking about what can be done with that waste (Despeisse *et al.*, 2012). This thinking leads to the developing web of interaction among organizations producing wastes which were later defined as IS (Gibbs and Deutz, 2005; Lombardi and Laybourn, 2012). The notion of IS emerged from a biological perspective, the term "symbiosis" represents relationships among closely located different kinds of species with the purpose of receiving mutual benefits (Ehrenfeld and Gertler, 1997). While the term symbiosis in the industrial perspective indicates the physical exchange of resources in the form of energy or materials among individual companies to receive mutual benefits. IS focuses on collaborating companies from different industrial sectors to achieve resource efficiency (Ehrenfeld and Gertler, 1997).

Chertow (2000) and Lombardi and Laybourn (2012) defined IS as a collective approach of numerous industrial actors to convey sustainability and gain competitive advantage through the exchange of physical and psychological resources. The study field of IS mainly focuses on developing linkages, relationships, and collaboration structure of creating an industrial ecosystem (Lombardi and Laybourn, 2012) while IE is broadly concerned regarding the principles of material flows sharing (Erkman, 1997; Sakr *et al.*, 2011; Saavedra *et al.*, 2018) to create an IS system**.** IS takes place at the inter-firm level as part of the industrial ecology approach with the collaboration of different organizational sectors in proximity (Chertow, 2000). Numerous literature described the IS as a process where "the waste or by-product of one organization becomes a source of raw material for another organization" (Frosch and Gallopoulos, 1989). In other words, it can be said that in an IS set-up the resources are utilized in a way that will ensure receiving maximum efficiency from a single material.

Ehrenfeld and Gertler (1997) first mentioned the concept of IS. According to them the key objective of developing an IS (collaboration) network is to introduce a circular flow of materials. Actors involved in the symbiotic network will share resources (physical and non-physical) to achieve collective benefits. Such as the waste from one company in the area will be utilized by another actor for material production to closing the loop of material flow. In addition to that, the participating actors will share knowledge, infrastructure to accelerate the efficiency of the processes (Lombardi and Laybourn, 2012). Therefore, it can be acknowledged that IS is a collaboration platform of organizations to practice industrial ecology principles and to receive economic benefits (Bansal and Mcknight, 2000; Yeo *et al.*, 2019).

2.2.1 Types of industrial symbiotic model

In history, countless examples regarding trade-off between resources can be easily found. For example, a blacksmith used to trade the equipment with a butcher in exchange for meat. However, all kind of relationship based on resource sharing is not considered as an IS model. In this odyssey, Chertow (2007) defined three dimensions of resource sharing to be considered an industrial network as a symbiosis process. First, the primary source of raw materials should be an effluent of other participating organizations in the network. This highlights the fact that virgin materials can't be utilized in any of the operating processes (Roberts, 2004). Secondly, the organizations participating in the network must utilize the common infrastructure, logistic services, common management system. Thirdly, the whole community should share a joint vision and move toward the development of a sustainable ecosystem. Most importantly, the emergence of a successful IS facility requires sharing a joint vision from all the participating organizations (Herczeg, Akkerman and Hauschild, 2018). This vision can be a result of any specific resource need, can be initiated fully with an economic incentive, or even can be a regulative pressure which has driven different companies together to resolve the issue.

Lombardi and Laybourn (2012) mentioned "collaboration" and "geographical proximity" as the key dimensions of an IS process. According to them in an IS system different industrial actors collaborate to exchange physical and non-physical resources in close proximity. Further, it has been argued that the distance among different actors can be in the form of psychological or physical. The benefits of minimum physical distance are lessened transportation cost while minimal psychological distance is required to develop trust (Ehrenfeld and Gertler, 1997). Based on the literature describing the emergence process of different IS systems, three different ways of the IS evolution model have been outlined: self-organized, facilitated, and planned.

Self-organized IS model: This model is generally initiated by co-located industrial actors with a perspective of solving a common crisis (Mirata, 2004). Incentives to create a symbiotic relationship is purely driven by the self-motivation of actors' mainly to receive business benefits. In some cases, companies operating in a locality may join together due to the regulative pressure of reducing emissions or to cut down the cost of production by sharing necessary products, equipment, or services. The interesting factor of the self-organized model is that the expansion of the network takes place through an autonomous approach (Boons *et al.*, 2017). The industrial actors are responsible to find suitable partners for their operations, make negotiations, and ensure values through collaboration. In this context, Chertow (2000) proposed an **"**anchor-tenant model" as an evolutionary way of initiating resource partnerships to organize IS. According to this model, in the initiation phase, a symbiotic network should involve a few big organizations as anchor firms to ensure the continuous flow of materials. There is a contradiction while planning the network whether the firms should be selected based on streamlines or new business opportunities should be created with a prior planning of the firm. Either way, there will be the presence of anchor companies as a resource provider and will require including firms in a symbiotic relationship to utilize the resources as tenant firms. One key important fact here is that the anchor companies need to ensure an abundant supply of resources to ensure the viability of the network for a longer-term.

Lambert and Boons (2002) mentioned that the self-organized IS system mostly comprise of heavy industrials, joined spontaneously to improve operations. For example, the most successful Kalundborg IS originated from the need for surface water in a specific area (Chertow, 2000). A self-organized symbiosis model can also originate with the exchange of materials within an organizational boundary (Chertow and Ehrenfeld, 2012). For example, vertically integrated companies can engage in a symbiotic relationship by sharing resources. The main motivation of actors to initiate such practices is improving the eco-efficiency of operations (Costa, Massard and Agarwal, 2010). As the network evolves the boundary within organizations gradually becomes invisible, the symbiotic nature becomes more exclusive and the by-product exchange happens at the inter-firm level (Boons, Spekkink and Mouzakitis, 2011). The incentives of actors to participate in the collaboration can be in various forms, such as it can be an expansion of the business network, introducing eco-efficient operation or purely economic drivers (Chertow and Ehrenfeld, 2012). As companies get involved in the network autonomously, most often the self-organized model results in developing a strong multiple stakeholder network compared to other models (Boons *et al.*, 2017).

Facilitated IS model: Paquin and Howard-grenville (2012) mentioned the facilitated IS model as a middle approach of planned and self-organized one. The facilitated IS system is organized by a third-party organization that can be owned by either a public or private sector. However the organization is not involved in the IS, (Costa, Massard and Agarwal, 2010) rather it can just create a marketplace for by-product exchange for industrial actors. The role of third-party actors is to maintain transparency in the overall process, showing the opportunity of by-product exchange and encourage to increase the number of material exchanges among industrial actors. To progress with the symbiotic structure the facilitators may take an advanced role rather than just opening the secondary materials marketplace. At this stage, the actors design a collaborative learning approach among industrial actors to foster the development of trust among them (Park, Duque-Hernández and Díaz-Posada, 2018). Such an approach requires industrial actors to openly communicate with each other and share explicit knowledge. Here, the role of the third-party actor will be to facilitate and management of the interactions among actors rather than providing any information actually (Paquin and Howard-Grenville, 2012).

A recent analysis of IS evolution shows that even an existing IS model can facilitate the emergence of a new IS model (Schlüter, Mortensen and Kørnøv, 2020). For instance, the facilitators can adopt a suitable concept of IS from the international level and then replicate the concept in a regional or local context (Boons *et al.*, 2017). Here, the role of facilitators initiates with technical data collection to the organization of informal meetings, acts as a decision-maker, and negotiate (Schlüter, Mortensen and Kørnøv, 2020). The main idea is that the facilitator will develop the whole concept of IS as a pilot phase to facilitate the development of local or regional level symbiosis development (Boons *et al.*, 2017). The pilot project will be replicated at the industrial scale, the collaboration network will include actual actors. A good example of a facilitated symbiosis model is the National IS Programm in the UK (Mirata, 2004). In this model, the regional actors set up a coordinating entity to facilitate interaction among actors in the platform. In some cases, a third-party organization might get involved in an existing IS network to take the concept to next level (Schlüter, Mortensen and Kørnøv, 2020).

Planned IS model: The governmental actors either from the national, regional, or local levels are the primary initiator of a planned IS model (Lowe, 1993). Based on the geographical scale the IS is recognized as regional, local, or national level implications (Boons, Spekkink and Mouzakitis, 2011). According to the context of the region, the governmental actors formulate strategies, policies, and action plans to coordinate the IS linkages. However, in the case of governmental actors organized IS, the result of action plans is monitored to evaluate the performance and if necessary the national IS policies

are changed or renewed. Due to the economic benefits achieved through IS encourage governmental actors to initiate the process which is broadly known as EIP (Lowe and Evans, 1995). While Boons, Spekkink, and Mouzakitis (2011) named such organizations as regional IS model.

According to Chertow (2000), EIP represents a community of local actors, manufacturing different products and services by co-operating with each other to achieve a common value that can not be attained at an individual level. This community might include actors from local firms or municipalities which share resources (water, energy, heat, manpower) to enhance economic performance in a sustainable way (Pakarinen *et al.*, 2010). Hence, the main idea behind the EIP establishment is to improve the financial performance of contributing organizations and improve the environmental and financial situation of the locality (Yu, De Jong, and Dijkema, 2014). The organization of an EIP can be initiated in two ways: a new planned EIP model or transformation of an existing IS to an eco-industrial model (Boons *et al.*, 2017). Most of the successful EIPs have emerged through the transformation of an already existing IS network (Mathews and Tan, 2011). However, till now limited researches have been conducted to recognize the attractiveness of an existing facility to initiate the thinking of a new industry cluster (Schlüter, Mortensen and Kørnøv, 2020). Nevertheless, the primary concern of this research is to understand the collaboration process (public-private) development toward an IS. The planned IS model incorporates actors from public and private sectors, therefore the evolution of this process is discussed extensively in the later section.

3. ASSIMILATING THE PROCESS OF INDUSTRIAL SYMBIOSIS

This chapter will look toward the collaboration process development of the industrial symbiosis (IS) systems. Therefore, this chapter will investigate IS systems from a processual approach. Next, the chapter will outline the ecosystem structure of an IS set-up primarily in the form of an eco-industrial park (EIP), will analyze what kind of actors are present and how their role evolves. Following that, the drivers or inhibitors impacting the collaboration process development among actors, along with affecting the activities of comprehensive system development will be presented. At the end of this chapter, a theoretical framework will be represented by combining the IS process development concept with the identification of ecosystem actors and driving or inhibiting factors impacting the entire IS process development.

3.1 Process analysis of industrial symbiosis development

The concept of industrial symbiosis got more recognition in recent years due to increased concern among industrials regarding the scarcity of natural resources (Ehrenfeld, 1997; Heeres, Vermeulen and De Walle, 2004). Over a brief period of time academics focused on developing knowledge on the emergence process of an IS system (Chertow, 2007; Gibbs and Deutz, 2007; Boons, Spekkink and Mouzakitis, 2011; Yu, Han and Cui, 2014; Schlüter, Mortensen and Kørnøv, 2020). Some literature argued that an independent symbiosis structure is more effective (Chertow, 2007) while others claimed that the presence of a third-party organization is more practical in initiating the process (Gibbs and Deutz, 2007; Paquin and Howard-grenville, 2012). With the purpose of contributing to the existing knowledge of the IS emergence process, this research also focused on the organizational process perspective toward the IS systems. Boons, Spekkink, and Jiao (2014) also referred to a processual approach to recognize the long-term emergence pattern of an IS system. The term “process” refers to continual changes happening over a period until the end result is achieved.

According to Boons, Spekkink, and Jiao (2014) the evolution process of an IS network encompasses several events that are considered as the “building block” of initiating collaboration among different actors. Hence, they suggested three phases “emergence”, “development” and “decline” of an IS network development based on resource sharing

synergies. Chertow (2007) defined the IS development stages as “sprouting”, uncovering”, “embeddedness” and “institutionalization” and proposed the “anchor-tenant” model of initiating IS relationships. On the other hand, Paquin and Howard-grenville (2012) categorized the facilitated IS model network development phases as “pre-network”, “earlier network” and finally “later network” development. Similar to those approaches Doménech and Davies (2011) divided the IS development process into three phases: “emergence”, “probation” and, “development & expansion”. Furthermore, the sequence analysis of different critical events can lead toward a better understanding of the activities that are necessary to build relationships (Boons, Spekkink and Jiao, 2014). Nevertheless, the IS evolution phases described by Doménech and Davies (2011) majorly focused on the process of building connections among different actors and embeddedness; therefore this research further progress with this phase logic to analyze IS process development.

In the “emergence phase” of an IS network, only primary relationships are formed with required actors. The actors involved at this stage, mostly act as the core actor and define the extent to which firms should co-operate (Doménech and Davies, 2011). Again, every actor in the network needs to be connected with another by sharing at least one product or service (Ashton, 2008). The actors in the core of the network are the most interactive ones, develop a better relationship with other actors, and have a greater impact on organizing the whole network as a system (Boons *et al.*, 2017). Following the emergence of a network, comes the “probation” phase where the actors already involved in the network have a mindset of co-operation, gain expertise on the current network and look for opportunities to involve potential actors for resource exchange or business from other sectors (Doménech and Davies, 2011). Already established relationships based on material exchanges, practical learnings and co-operation led toward the development of trust among participating organizations. The collaboration process development phases of IS systems is outlined in Figure 2.

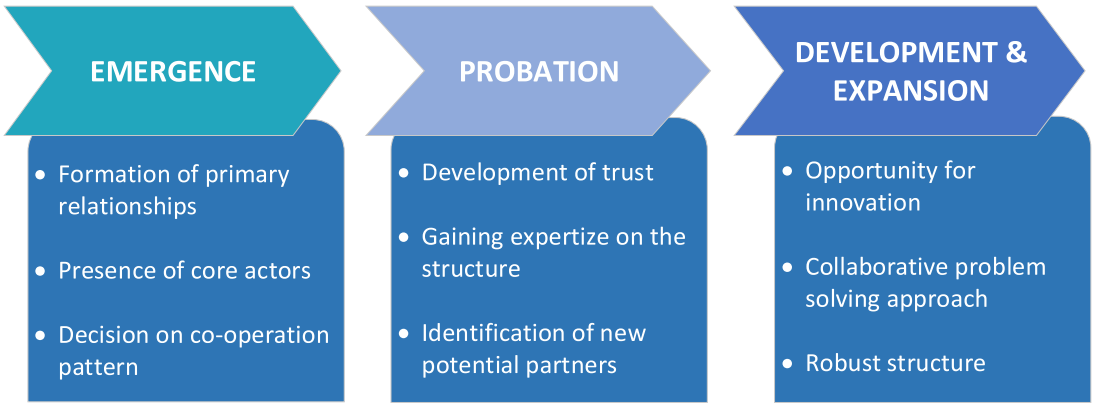

Figure 2. *IS process development phases (based on Doménech and Davies* 2011*).*

As described in figure 2, the final phase of an IS network is "development & expansion" where the engaged actors collaboratively approach toward solving the problems in the network, looking for innovativeness by sharing risks (Arranz *et al.*, 2019). The prevailing relationships among actors become robust based on co-operation and trust gained from daily operation experience, and new partnerships are created. Hence, the term actors might represent individuals, organizations, or even a cluster of individuals (Ashton, 2008). During the evolution process actors of individual firms belonging to the same category (can be based on products or process) remain in close interactions for daily operations. Nevertheless the evolution of the IS system as a long-term process, due to the essence of a place-based exchange the emergence process is impacted by different dimensions like social, technical, institutional, etc. (Yu, De Jong and Dijkema, 2014).

Ashton (2008) analyzed the development of relationships and interactions among the actors from a social network theory perspective. Customarily industries are established in a societal system, social and cultural aspects fabricate the behavior of the actors involved in the network (Doménech and Davies, 2011). Therefore, the formation of an IS network and establishing relationships among firms are greatly influenced by social aspects (Ashton, 2008; Doménech and Davies, 2011). The customs, values, and beliefs shared in the society shape the interaction modes that greatly impact the linkage probabilities among firms (Ashton, 2008). Thus, analysis of social factors like culture, values will primarily help to understand the evolution process of an IS network in a specific area. It has been emphasized that trust and co-operative mindset of actors are the key social issues affecting the emergence of an IS system (Yeo *et al.*, 2019). Nonetheless, values, norms, relationships, establishment of trust, co-operation among organizations participating in the network evolve (Ashton, 2008).

Although from a technical perspective the material flows information is considered as a primary element to initiate the collaboration, yet it is not sufficient to attract actors from individual firms in collaboration (Yu, De Jong and Dijkema, 2014). Collaborating multiple actors from different sites for business purposes without compromising the benefits of each actor is the most crucial element while constructing an IS process (Sakr *et al.*, 2011). Park et al. (2019) provided an overview of how IS systems should be organized to scale-up the business opportunity. The first strategy focuses on expanding the area of IS network development at the regional level. This will aid the opportunity for many organizations to join the network and will reinforce the structure of IS for the long term. In addition to that regional authorities, involvement in the network will secure the finance for infrastructure development, gaining trust from local people and businesses. Next, the strategy should be accumulating knowledge from past experiences regarding success and failure factors (Park et al., 2019). By acknowledging those factors, standard measures for progressing the IS structure should be formulated and marketing materials, seminars should be arranged. Promoting the concept will help to attract more organizations and will increase the credibility of the system. Table 1 provides examples of famous IS systems organized around the world with specifications on facts on how the system emerged and how the network was further managed by the actors.

Table 1. *Example of IS systems around the world based on literature.*

Name of the IS system	**Emerging process**	**Management**	**Reference**
Kalundborg Symbiosis, Denmark	• Self-organized • Based on specific resource need • In the early phase: one connection, 1960; grew to 4 by 70's. Real development started from '90s with 30 linkages.	• Established a team of co-ordinating actor	Chertow (2000)
National EIP, South Korea	• Existing industrial park to EIP • Three scaling up strategies: first phase: expansion of planned areas to the regional level, • Second phase: promotion of IS through standardizing the process and including bigger organization, • Third phase: regional development through large scale projects.	• Own Facilitation approach by regional EIP centers	Park, et al. (2019)
National Industrial Symbiosis Programme (NISP), UK	• Facilitated IS model • "Serendipity" played the key role in the initiation of IS • Developing embeddedness: structurally (resource exchange) or culturally (trust).	• Facilitating actor	Paquin and Howard-grenville (2012)

Industrial Symbiosis Network, Aalborg, Denmark	• The attractiveness of existing IS encourages the emergence of new ones. • Individual, organizational, institutional capacities are developed along the IS emergence process.		Schlüter, Mortensen and Kørnøv (2020)
Pulp and Paper Mill, Finland	• Gradually evolved into an eco-industrial system to control environmental degradation.		Pakarinen *et al.*, (2010)
TEDA, China	• Self-organized to policy-driven • Involvement of local govt.	• Local authority functions as co-ordinator.	Yu, Han and Cui (2014)
INES, RiVu, Moerdjik, Netherland	• Initiated by a local entrepreneur, with the involvement of regional authority as supervisor of finance • Financed on 50:50 by companies and local government.	• Consulting agencies/educational institutions. • Absence of an anchor-tenant model to prioritize each actor (local champions) • Presence of an employer's association as a communication platform.	Heeres, Vermeulen and De Walle (2004)
Fairfield, Brownsville, CapeCharles, the U.S.	• Regional or local government to improve the local economy condition	• Local community opinion • Fully financed by local govt.	Heeres, Vermeulen and De Walle (2004)

However, the symbiotic relationships can be initiated in diverse ways, for example, anchor companies like a power plant, chemical industry or agriculture firms look for tenants to share the side-streams or it can be otherwise. The first kind of arrangement is especially found in the private sector or self-organized symbiosis model (Chertow, 2000). On the other hand, in a planned model (EIPs) the side-stream flow remains fixed and requires identification of necessary actors (Lowe, 1993). The most suitable one is the combination of both ways, anchors can try to identify new tenants to grow the network and increase innovation opportunity. Neverthless Boons, Spekkink, and Mouzakitis (2011) stated that the development of an IS as a continual change process, where the actors involved in the process gradually evolve based on the scope of resource sharing, and finally, creating a robust structure of the IS system. The next segment will focus on the ecosystem structure of the planned symbiosis model specifically the IS systems organized in the form of EIP.

3.2 Ecosystem of industrial symbiosis

In recent years, academics conducting the analysis of complex business networks and their interdependent activities with an “ecosystem” approach (Aarikka-stenroos and Ritala, 2017). The term ecosystem was first mentioned by Moore (1996) from a business perspective to illustrate the importance of the co-evolution of industrial actors within its business environment to attain mutual value. He defined the business ecosystem as a “community of economy” which involves customers, governmental organizations, competitors, individuals, media that need to act collaboratively with the alignment of a vision. Further, he mentioned that the key to the success of a business ecosystem is a competent leader who will define the scope of greater value potential for all the ecosystem actors achievable only through co-operation. On the other hand, Kapoor (2018) considers the ecosystem approach as more of a buzzword to initiate incompatible concepts of analyzing business networks. Nevertheless, Adner (2016) defined ecosystem as a structure aligned with multiple set of actors who interacts frequently to actualize a central value proposition. In this odyssey Aarikka-Stenroos, Ritala, and Thomas (2021) also adopted an ecosystem approach toward the organization of CE activities, defined as “CE ecosystem”. They defined CE ecosystem “as communities of hierarchically independent, yet interdependent heterogeneous set of actors who collectively generate a sustainable ecosystem outcome.” Similar to the approach suggested by Adner (2016) the IS ecosystem also comprises multilateral actors from diverse fields co-ordinated with a shared objective and incorporate the notion of CE ecosystem (Aarikka-Stenroos, Ritala and Thomas, 2021) as the operational activities in IS mainly function following CE principles. Therefore, the IS concept can be contemplated from an ecosystem perspective as well.

An IS system is recognized as many terms like IS networks (ISN) (Schlüter, Mortensen and Kørnøv, 2020), co-ordination networks, EIPs, eco-industrial clusters (Baldassarre *et al.*, 2019), etc. Traditionally, when IE principles are implicated at the local-level to formulate *industrial symbiotic structure*, the *network is mostly termed as an EIP* (Cote and Cohen-Rosenthal, 1998; Taddeo, Simboli and Morgante, 2012; Boons *et al.*, 2017). According to Yu, De Jong, and Dijkema (2014) EIPs are a “policy-driven” approach for implying IE strategy in a locality. EIP establishment aims to minimize the amount of waste accumulated in a locality and achieve economic benefits through environment-friendly business operations (Tudor, Adam and Bates, 2007). Analogous to the business ecosystem defined by Moore (1996) EIPs are referred as a “local business community” which forms a symbiotic relationship by collaborating local actors and following the principle of industrial ecology (Bai *et al.*, 2014). Therefore, the ecosystem approach to ana-

lyze the diverse actors involved in an EIP, and the co-evolution pattern of extensive ecosystem actors while defining the ecosystem composition will be a great way (Aarikka-stenroos and Ritala, 2017).

Additionally, the IS literature provides a comprehensive framework on the ecosystem of an EIP (Bain *et al.*, 2010). Heeres, Vermeulen, and De Walle (2004) and Lowe and Evans (1995) mentioned that an EIP ecosystem commences on a business network with the collaboration of actors from the local government level or individual firm level who jointly focus on economic development. Similar to that Boons *et al* (2017) stated local level organizations as the core actors of an EIP ecosystem. Chertow (2000) emphasized that the actors involved in the EIP ecosystem share the common infrastructures for daily operating processes and jointly responsible for the management of those facilities. From these analogies, it can be noted that an EIP ecosystem embraces the presence of local and regional government, environmental organizations, economic development agencies (Lowe and Evans, 1995), residents (Herczeg, Akkerman and Hauschild, 2018) along with private sector stakeholders (Doménech and Davies, 2011) such as local company representatives, industrial and economic community leaders**,** research and education institutes (Boons, Spekkink and Mouzakitis, 2011; Lombardi and Laybourn, 2012). This research particularly chose *to analyze the EIP ecosystem structure* as it embeds the *public and private sector organizations' collaboration level* to organize an IS system.

The progress of a co-operative EIP ecosystem requires the existence of a well-functioning institutional arrangement (Mirata, 2004; Boons, Spekkink and Mouzakitis, 2011). Besides, Ehrenfeld (1997) indicated policies as a key enabler of EIP network development. The regional policies are formulated by local governments and therefore, the role of regional authorities in EIPs will be to implement policies that will abide by individual firms to join the network (Lowe and Evans, 1995). Additionally, existing policies can be altered to support EIP development and relaxing the infrastructure, resource sharing process among firms (Mirata, 2004). Yu, Han, and Cui (2014) mentioned the main role of the local government in EIP development is to promote the platform among local firms. Apart from that, the local actors (public) might provide the necessary funding to develop the infrastructure, utilities, and ensuring necessary facilities (Taddeo, Simboli and Morgante, 2012). Regional authorities are also responsible for auditing and appraising the performance of local companies, and influence those to collaborate in the EIP ecosystem (Geng *et al.*, 2009; Costa, Massard and Agarwal, 2010).

The core of an EIP ecosystem is the individual firm level actors (Tudor, Adam and Bates, 2007; Chertow, Ashton and Espinosa, 2008; Zhang, Zheng and Fath, 2015). Initially, the

private organizations working in the locality join the collaboration platform. However, individual organizations from private sectors do not primarily focus on network development, rather their motive is achieving economic efficiency through the network. Alongside, another significant role played by public authorities as an influencer (Costa, Massard and Agarwal, 2010; Paquin and Howard-grenville, 2012) to drive other organizations to join the platform. Alongside this, EIPs are considered a great opportunity for small and medium-sized enterprises (SME) to conduct innovative business operations to develop their competency (Puente, Arozamena and Evans, 2015). Besides, SMEs look for support from governmental authority to integrate sustainability which is easily accessed through participation in the EIP system (Patricio *et al.*, 2018). Thus, the overall EIP structure function as regional development and growth opportunity, which is the main motive of a governmental body to participate in such projects.

Public sector organizations like NGOs, regional or local business development platforms, educational institutes also become part of the wider ecosystem of a symbiosis platform with the purpose of increasing sustainability in the region (Boons, Spekkink and Mouzakitis, 2011). Furthermore, EIPs is considered a hub of eco-innovation practice to introduce innovative products and encourage company actors to perform accordingly (Arranz *et al.*, 2019). Consequently, the EIP ecosystem necessitates a sub-ecosystem of research and educational institutes to foster innovation practices and support business activities (Lombardi and Laybourn, 2012). Hence, the local government playing the role of intermediaries and source of finance has been resulted in bringing more success in the EIP advancement (Arranz *et al.*, 2019). The actors of the innovation ecosystem emphasize broadening their expertise in the relevant fields, maintain a connection with the company actors (Gilsing *et al.*, 2008) over attaining a part of the mutual value of the EIP ecosystem (Aarikka-stenroos and Ritala, 2017). Thus, it can be acknowledged that the broader EIP ecosystem can be characterized as a combination of the business and innovation ecosystem. The business ecosystem is simply driven by financial benefits to be achieved through collaboration while the innovation ecosystem gains part of the value by supporting the progress of the business ecosystem. Based on the literature view from different sources regarding the ecosystem actors present in an IS system organized in the form of an EIP has been structured in Figure 3.

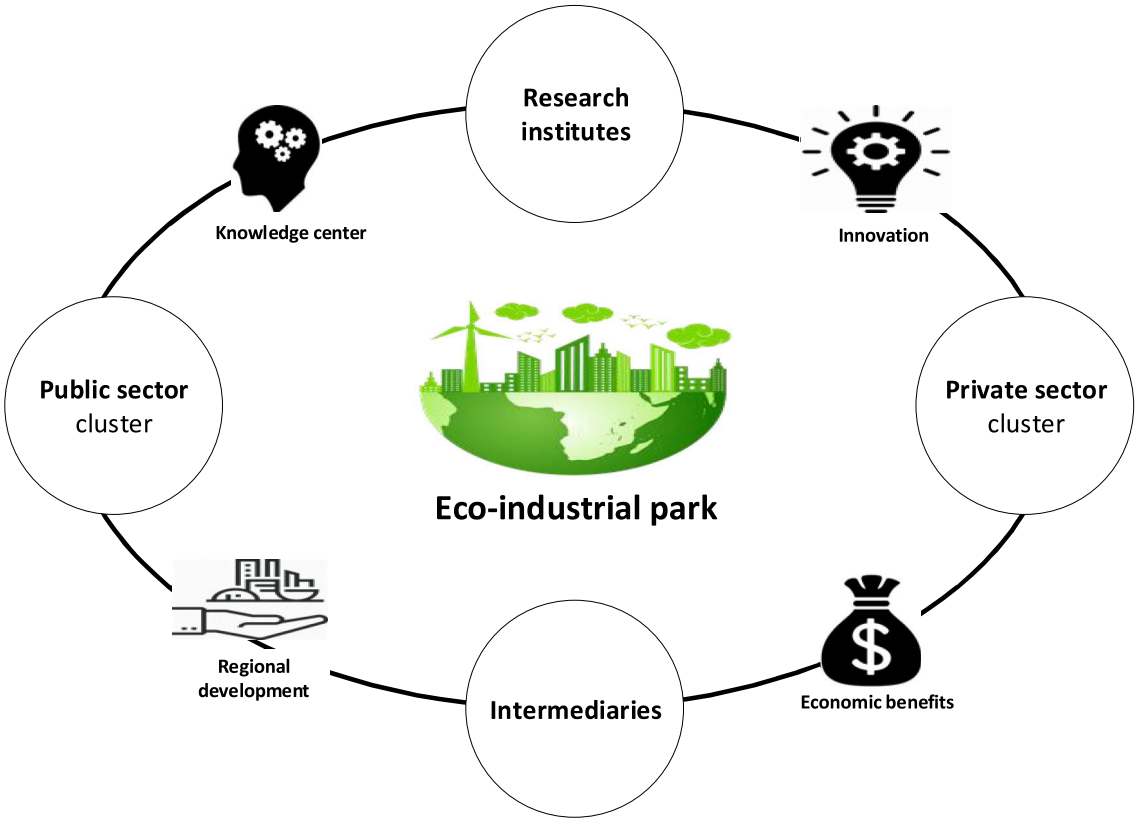

Figure 3. *Organizational clusters of an EIP ecosystem.*

The actors involved in the ecosystem of an EIP are not always tied into a direct relationship rather collaborates to attain a shared vision (Aarikka-stenroos and Ritala, 2017). The EIP ecosystem needs to be analyzed from a network management perspective to identify how the ownership is organized. As an EIP includes actors from public and private sectors there remains a significant difference in values, culture, operating mode among organizations. Exploration of numerous eco-industrial initiatives indicates that the ownership can be organized either in a “centralized” or in a “crossed” way (Ehrenfeld and Gertler, 1997). In the centralized structure, the whole platform will be financed by one organization. This kind of arrangement is especially visible in EIPs, where the platform is owned by the government, and necessary funding for developing the infrastructure is arranged that way. The profit is divided among the participating organizations based on the contract prepared. On the other hand, in the cross-ownership structure, few potential actors are responsible for platform development. These actors are held responsible for all finance-related risks and transactions. Public organizations in the municipality like waste management companies, water treatment centers, or energy suppliers can lead the EIP development as anchor companies by providing necessary infrastructure or co-operating with local firms (Korhonen, 2001).

Moreover, participation in an IS ecosystem facilitates the capacity development of the involved actors at three different levels: individual, system, and institutional level (Mortensen and Kørnøv, 2019). For instance, participation or collecting information from an IS network, aid the knowledge development of an individual at the practical level, an individual can gain expertise on how a business network can be developed. Such growth at the individual level will further impart to the progress of system-level thinking. An individual's tacit knowledge while participating in an IS is converted into explicit contributing toward the organizational-level progress. Finally, the actualization of benefits from the organizational level comes in the form of resource sharing, cost-effectiveness that contributes toward overall institutional level capacity development (Boons, Spekkink and Mouzakitis, 2011). Thus, the scope of attaining new business partners, developing relationships at the regional level motivates the local company actor to collaborate in an IS ecosystem. Therefore, companies already connected to an IS platform, tend to be more interested to join a new one. Many studies have been performed to recognize the specific pattern of successful symbiosis relationship development so that the exact approach can be replicated in other areas. Yet, understanding the ecosystem structure of an EIP is still in the development phase and provides more scope to be studied further (Heeres, Vermeulen and De Walle, 2004).

3.3 Factors impacting industrial symbiosis process

In literature, many examples of IS network development have been recognized. Implementation of IS systems in the form of EIPs (Gibbs and Deutz, 2007) is still in the emerging phase at the global level and only a few of the established EIPs are operating with full functionality (Sakr *et al.*, 2011). The development of an IS system requires the involvement of multiple stakeholders from different levels and meeting the objective of each actor is quite challenging. An IS process development requires collaborating actors from the public and private sectors (Lowe, 1997). The incentives of actors to join the platform are quite different, for example, companies from private sectors largely focus on receiving economic benefits (Costa, Massard and Agarwal, 2010; Sakr *et al.*, 2011) while public sector actors like regional authorities predominantly focus on bringing environmental sustainability, regional development (Boons *et al.*, 2017). Nonetheless, the emergence of an EIP requires sharing a common vision among all the actors involved, and the main driver to engage all actors has been defined as receiving economic benefits in many literatures (Roberts, 2004; Sakr *et al.*, 2011). Therefore, researches have been conducted to identify the factors impacting the collaboration process development

among those heterogeneous stakeholders. In this research, the factors bringing a positive change in the development of an IS system have been recognized as “drivers” while the factors slowing down the organization process have been stated as “inhibitors”.

de Jesus and Mendonça (2018) exploited a systematic approach toward categorizing the driving and inhibiting factors emerging throughout an eco-industrial initiative. These driving or inhibiting factors might already exist in the institutional settings such as existing policies (Desrochers, 2004), or can emerge from socio-technical settings (Lombardi, 2007; Sakr *et al.*, 2011; Yu, De Jong and Dijkema, 2014). These factors impact the development of an IS system in different ways, for example, those can be directly related to linkage creation among actors or can emerge along the process of organizational activities. Nevertheless, de Jesus and Mendonça (2018) used the terms “soft” and “hard” to make a distinction between the non-technical and technical factors impacting the organization of activities. To be more specific the term “soft” denotes diverse institutional, social, and environmental considerations that adhere to the capability of driving or inhibiting the progress of eco-industrial arrangements (de Jesus and Mendonça, 2018). While the term “hard” represents economical and technical factors that are essential to bringing a change in the system. The impact of hard factors is directly visible in an IS system such as cost reduction opportunities, business relationships, technologies; whereas soft factors influence different activities happening in an IS process in an indirect way such as trust is the root of initiating collaboration. Focusing on the above-mentioned categorization approach this paper also tries to outline diverse driving or inhibiting factors impacting the organization of IS systems. However, the identified driving and inhibiting factors in the theoretical part of this research is mainly based on the existing literature analyzing the organization of EIPs in different parts of the world. Nevertheless, it is difficult to suggest a concrete set of driving or inhibiting elements for all the EIPs, as these factors vary a lot depending on the culture, norm, and values of the locality and the actors involved (Ashton, 2008).

3.3.1 Soft factors

Institutional factors

Legislation: Studies on successful IS development process indicates that policies or regulative pressure can function both ways as a driver or as an inhibitor. Environmental legislations and strategies are generally set by the governmental body and the regional authorities remain responsible to supervise the companies for a specific locality (Costa, Massard and Agarwal, 2010). Despite the fact that EIPs can offer a large amount of

financial benefits, the actors from individual companies remain resilient to participate in EIP projects (Sakr *et al.*, 2011). In many cases, the reason behind this can be that the actors are ignorant of the benefits receivable, or lacking capabilities to participate. Therefore, Gibbs and Deutz (2007) defined governmental legislation as a key enabler to engage individual firms in the network. Many industrials have joined forces because of the environmental law set by the govt for waste reduction. Zhang and Wang (2014) also mentioned external pressure from regulatory authorities can either drive or inhibit the development of an eco-industrial arrangement. When planning an EIP, the government should design the regulation in a way that will support the development of the network. The regulations should support the knowledge sharing environment, infrastructure development, political actor involvement, and creation of business relationships (Tudor, Adam and Bates, 2007). Yet, the existing regulations might inhibit the progress of an EIP development (Mathews and Tan, 2011; Yu, De Jong and Dijkema, 2014). Heeres, Vermeulen, and De Walle (2004) and Gibbs and Deutz (2007) responded in a similar way that legislations often create barriers to conduct industrial activities and limit the growth of EIP.

Powerful authority: Zhang and Wang (2014) mentioned that the presence of powerful authorities from different societal or organizational level can drive the development of an EIP in three ways: coercive, normative, and mimetic. For instance, government or any environmental agency (Chertow, 2007) can enforce individual firms to integrate environmental sustainability thinking into their operating processes is referred as coercive drivers. Similarly, an important stakeholder of the IS ecosystem can drive normatively other stakeholders to embedded sustainability in their operations. Contrastingly to the normative driver, an individual firm can mimic the environmentally friendly operating process of other potential actors in their process. Presence of political actors can hinder the development of an EIP if the values are not communicated properly (Heeres, Vermeulen and De Walle, 2004). The political actors mostly conceptualize EIPs as a way of regional development by creating employment opportunities while companies consider EIPs as a pure business platform (Boons, Spekkink and Mouzakitis, 2011). Such, differences in value can hinder the progress to a great extent and some companies resist participating in the project (Desrochers, 2004).

Social factors

Trust and co-operation: Trust (Gibbs and Deutz, 2005; Zhang and Wang, 2014) and co-operation (Heeres, Vermeulen and De Walle, 2004; Taddeo, Simboli and Morgante, 2012) among actors are key influencing factors to create business relationships. In an IS

platform, company actors need to co-operate with each other, share business secrets and knowledge for different operating process development. Trust is the key virtue that can embed actors in a business relationship (Murphy, 2006). Without trust among actors involved in the ecosystem will tremendously slow down the collaboration process toward the development of the overall system. Business relationships established based on trust and co-operation in the processes can recede the psychological distance among actors and can elevate the IS process development ineluctably (Gibbs and Deutz, 2007). One of the key challenges faced by actors while organizing collaboration is the conflicting perspectives of different stakeholders (Afshari *et al.*, 2018). As the network comprises a variety of actors, the establishment of a mutual value might require some participating actors to compromise values at the individual level, creating conflict at the system-level. Thus the creation of a co-operative mindset among all the actors involved indicates plenty of challenges.

Charismatic leader: Sakr *et al* (2011) mentioned the importance of having a charismatic leader to the successful emergence of an IS network that can be also recognized as a cata-person, champion, or hero. Such a leadership approach can be solely initiated and by an individual person from an organization or even include a cluster of a few similar minded people from different companies. Although this person might have made a financial investment in the platform, the main motivation of engagement is not receiving economic benefits only. Rather, the person set the strategy for network development, communicate the vision among actors, collaborate, motivate, and drive actors for progressing the platform (Boons, Spekkink and Mouzakitis, 2011). The actor or person remains solely determined to establish the platform and possess the capability of moving actors toward reaching the ultimate objectives. The main role of this leader will be collaborating actors through his personal expertise without broadening knowledge of technical factors. In some cases, rather than just being an individual it can represent a group of people who are activiely involved for the IS development (Taddeo, Simboli and Morgante, 2012). Therefore, the presence of such a person in the network can catalyze the IS developments.

Relationships: Frequent interactions among participating organizations is the most crucial element to thrive an EIP progress (Heeres, Vermeulen and De Walle, 2004). The willingness of private company actors to share information, resources and time drives the platform development in the most prominent way compared to initiatives taken by the government. The presence of active associations to guide and educate others on the value receivable from the platform can drive organizations to participate in the collaboration. Lack of information-sharing practices specifically from private sector companies

inhibits the EIP development to a great extent (Heeres, Vermeulen and De Walle, 2004; Brunet-Navarro *et al.*, 2018).

Environmental factors

Corporate sustainability: Afshari *et al* (2018) introduced the term “corporate sustainability” referring to engage all the stakeholders in activities that will increase the sustainability of the organizations without impacting the needs of forthcoming stakeholders. EIPs are considered as the gateway of such practices, as it collaborates actors to perform environmentally sustainable business operations (Roberts, 2004), yet the opportunity of engaging more actors for sharing resources is always kept open with declined environmental degradation. The most important environmental driver in EIP operations is the conservation of natural resources (Risse, et al., 2017).

Green economy: EIP initiatives not only focuses on the sustainable mode of industrial operation with the conservation of natural resources but also include a strategy to diminish the carbon emission level. Present European policies strategize to reduce the carbon emission level specially from energy sectors with the utilization of renewable sources for energy production. Keegan *et al.* (2012) mentioned that the use of biomass as an energy source in place of non-renewable resources can be promoted with the implication of policies like increased taxation over carbon emission. When industrial firms collaborate in exchange for resources (wastes) can reduce CO2 emissions to an optimum level (Zhang and Wang, 2014).

Afshari *et al.* (2018) further mentioned that the possibility of measuring the impact of carbon emission reduction and the benefits achieved through it can significantly drive individual-firm level actors to engage in the system. IS systems are developed to decline carbon emission levels, lessening global warming and climate changes, overall encouraging environmental sustainability. Besides improved environmental performance will help individual firms to create a green image that will attract consumers and governmental actors (Zhang and Wang, 2014). Further, governmental institutes can provide financial incentives to support green initiatives and consumers also prioritize green products.

3.3.2 Hard factors

Economical factors

Cost reduction opportunity: Prior to participation in any collaboration platform, companies primarily emphasizes the economic or business benefits to be achieved from it (Gibbs and Deutz, 2007). Afshari *et al.* (2018) mentioned a strong inhibitor to create symbiosis

among companies is the lack of value measurement tools in terms of economic gain. When organizations join forces, it offers value creation opportunities for all the actors involved and part of the value is shared by every actor present in the network (Gibbs and Deutz, 2007). An IS network is organized with an aim of providing financial value to the actors. Roberts (2004) defined economic efficiency as the key driver of collaborating companies for an IS process while Sakr *et al* (2011) mentioned economic value as the second most important factor for an IS system to succeed. A symbiotic network can cut down the operating cost of companies to a great extent. First of all, materials utilized in different operating processes are collected as wastes from another company which ensure the abundant supply of resources. Here, the supplier firm obtains a part of value by minimizing the cost of the waste treatment process to a certain level (Desrochers, 2004). The materials collected from secondary sources are substantially low-priced compared to virgin materials. The companies are located in proximity, eliminating transportation costs, and cost of finding suitable suppliers, transaction cost (Mirata, 2004; Geng *et al.*, 2009; Mathews and Tan, 2011). Thus, an IS system diminishes the procurement cost to a great extent and the extent of cost reduction opportunity is a great way to attract individual companies to join the platform (Chertow, 2007).

Business relationships: Many companies consider IS as an opportunity to initiate business relationships. Small and medium-sized enterprises willingly participate in EIPs to create new business partnerships while local companies look for opportunities to grow at the international level. Pellenbarg (2002) mentioned that the presence of actors from renowned companies enhances the reliability of the whole platform and drives other small or medium-sized firms to join the network. Effective interactions among the participating organizations can accelerate the development of an IS network (Chertow, 2000; Heeres, Vermeulen and De Walle, 2004; Sakr *et al.*, 2011). Digital tools or platforms can be an efficient tool to engage actors and share information without complexity (Schlüter, Mortensen and Kørnøv, 2020). For example, the material flow data can be made available through a digital platform among the participants, this will facilitate trust among actors, and will provide a media to share knowledge.

Diversity of the network: The involvement of actors from diverse industrial fields catalyzes the expansion of network and attract individual companies (Tudor, Adam and Bates, 2007; Taddeo, Simboli and Morgante, 2012). If a planned IS model includes heterogeneous industrial processes from different sectors like forestry, chemical, plastics, metal recycling, it will increase the value creation opportunity and encourage a large number of industrial actors to engage in the processes. Firms will be able to find the most

suitable business partner for their network. Alongside, different industrial processes release a variety of materials, maximizing the possibility to experiment with new materials and creation new business opportunities (Ehrenfeld and Gertler, 1997; Walls and Paquin, 2015). Therefore, the existence of diversified industrial actors will adorn the symbiotic relationship creation opportunity.

Competitive advantage: The opportunity of gaining competitive advantage by participating in collaboration is referred as a key driver to engage company actors (Desrochers, 2004; Roberts, 2004). The global competition is increasing at an accelerating rate among industrials. This competitive pressure has enforced industrials to identify ways to achieve the market leader position by offering unique value to consumers (Chertow and Ehrenfeld, 2012). At present days consumers are more conscious and tend to purchase "green" products. Alongside, companies adapting sustainable production methods are recognized by international actors and the EIP system can function as a brand for companies to grow in the international market. Therefore, participation in EIP initiatives will be beneficial for both B2B and B2C perspectives for company actors.

Information flow: In an IS process the information related to material flow needs to be exchanged, as in practice there is a professional market for waste flows. This poses a significant hindrance in organizing IS systems (Sakr *et al.*, 2011; Yeo *et al.*, 2019). therefore the supplier and buyer of the end product are also uncertain. While Raabe *et al* (2017) mentioned the importance of knowledge and information sharing practices can significantly catalyze the development of an IS system, yet at the current situation, there is no established platform to collaborate actors for collaboration.

Technical factors

Geographical proximity: One of the key criteria of IS development is that the companies operating in a territory need to co-operate and collaborate for sustainable business operations (Roberts, 2004). While operating in proximity companies can result in bringing more cost and environmental efficiency for the system-level operations (Heeres, Vermeulen and De Walle, 2004; Taddeo, Simboli and Morgante, 2012). Closely located companies will interact more frequently, maintain transparency and such approaches will result in the creation of trust and a co-operative mindset among actors (Chertow, 2000). Therefore, geographical proximity has been defined as a key driver of organizing the IS network (Jensen et al., 2011).

Eco-innovativeness: Increased innovation capability or practices by individual companies participating in the collaboration can foster the process development of an IS (Arranz et al., 2019). Generally, companies initiate environmental innovation projects at

their own organizational level due to legislative pressure. However, the process of innovation requires continuous interaction among multiple actors interested in the system (Gilsing et al., 2008). These actors collaborate by sharing materials, information, knowledge, and risks to bring out the eco-innovative products in time. The eco-innovation activities consume a significant amount of financial resources and time making the process difficult to implicate at the individual level. While in an IS eco-innovation is considered as a potential source of the economy (Arena et al., 2018). The economic and environmental sustainability of an IS platform requires eco-innovation activities to achieve maximum resource efficiency and bringing out new innovative products.

Therefore, companies consider IS platforms as a great opportunity to initiate collaboration with other organizations. The operating environment of the symbiosis platform ensures an uninterrupted flow of information and transformation of knowledge required for innovation activities (Wang et al., 2012). Alongside, government-financed IS systems focus on improving the performance of the environment by motivating companies to conduct eco-friendly operations (Horbach, 2008). Besides, the IS ecosystem incorporates different national research institutes in the ecosystem to experiment with eco-friendly products and share knowledge with company actors for production and market purpose. However, an eco-innovation process development includes complex activities and uncertainties which resist companies to engage in such practices (Arranz et al., 2019). Technical and commercial failure in innovation projects context is a common paradox, which is perceived by the managerial body as a misuse of time and financial resources. An unsuccessful innovation project can cut down the operating budget resulting in the deploying overall progress of the system.

Digital measurement tools: Technologies can play a crucial role in the successful implementation of an IS model. The basic source of raw material for IS systems are wastes collected from domestic and industrial sectors. To ensure maximum efficiency of such resources requires efficient waste sorting processes and treatments (Husgafvel *et al.*, 2018). Application of technologies like sensors at the collection points to sort a different type of waste (waste bins) will increase the amount of total waste collected. If the wastes are sorted at the point properly, it will increase the overall efficiency of an IS system. Alongside, industrial wastes include different hazardous materials components, which can be easily detected with technologies to make the treatment process more effective. Different digital measurement tool needs to be installed to collect the information about the amount and type of material flows during the planning phase of an IS model (Winder and Bobar, 2018). Information on material flows will act as a key enabler to include individual firms.

Apart from the above-mentioned factors other aspects also impact the organization of IS activities. For example, Active participation from local residents by sharing their ideas and co-operating the platform development will be a driving force (Heeres, Vermeulen and De Walle, 2004). While a lack of infrastructure to initiate resource sharing practices can significantly hinder the collaboration process development among firms (Zhang and Wang, 2014; Jarre *et al.*, 2020). All the described soft and hard factors either driving or inhibiting the organization of an IS system is summarized in Table 2.

Table 2. *Soft and hard factors impacting IS activities.*

Soft factors		**References**
Institutional factors	Legislation (policies, environmental legislations, governmental legislation)	Ehrenfeld and Gertler (1997); Gibbs and Deutz (2007); Sakr *et al.* (2011); Taddeo, Simboli and Morgante (2012); Costa, Massard and Agarwal (2010); Mathews and Tan (2011); Zhang and Wang (2014); Yu, De Jong and Dijkema (2014); Heeres, Vermeulen and De Walle (2004);
	Powerful authority (political support, local government support)	Zhang and Wang (2014); Heeres, Vermeulen and De Walle (2004); Chertow (2007); Boons, Spekkink and Mouzakitis (2011); Zhang, Zheng and Fath (2015); Desrochers, (2004);
Social factors	Trust and co-operation	Gibbs and Deutz (2005); Zhang and Wang (2014); Heeres, Vermeulen and De Walle (2004); Taddeo, Simboli and Morgante (2012); Murphy (2006); Gibbs and Deutz (2007); Afshari *et al*. (2018);
	Charismatic leader	Sakr *et al* (2011); Boons, Spekkink and Mouzakitis (2011); Taddeo, Simboli and Morgante (2012); Brunet-Navarro *et al.* (2018);
	Relationships (communication, willingness, information sharing)	Heeres, Vermeulen and De Walle (2004); Keegan *et al.* (2012);
Environmental factors	Corporate sustainability	Afshari *et al* (2018)**;** Roberts (2004); Risse, Weber-Blaschke and Richter (2017);
	Green economy	Afshari *et al.* (2018); Keegan *et al.* (2012); Zhang and Wang (2014);
Hard factors		
Economical factors	Cost reduction opportunity (procurement cost, transportation cost, lower-priced materials, suppliers, transaction cost)	Desrochers (2004); Roberts (2004); Mirata (2004); Chertow (2007); Gibbs and Deutz (2007); Geng *et al.* (2009); Mathews and Tan (2011); Sakr *et al.* (2011); Herczeg, Akkerman and Hauschild (2018); Afshari *et al.* (2018)
	Business relationships (international networking, business network diver-	Chertow (2000); Pellenbarg (2002); Heeres, *et al.* (2004); Sakr *et al.* (2011); Schlüter, Mortensen and Kørnøv (2020);

	sity, new partnership opportunity, renowned company actors, anchor firms)	
	Diversity of the network (suitable partnership opportunity, new business opportunity, conflicting opinion)	Ehrenfeld and Gertler (1997); Tudor, Adam and Bates (2007); Taddeo, Simboli and Morgante, (2012); Walls and Paquin (2015);
	Competitive advantage	Desrochers (2004); Roberts (2004); Chertow and Ehrenfeld (2012);
	Information flow (material flow, market uncertainty, uncertainty of supplier and buyers of end products)	Sakr *et al. (*2011); Raabe *et al. (*2017); Arranz *et al.* (2019); Yeo *et al.* (2019);
Technical factors	Geographical proximity	Chertow (2000); Roberts (2004); Heeres, Vermeulen and De Walle (2004); Jensen *et al.* (2011); Taddeo, Simboli and Morgante (2012); Boons, Spekkink and Jiao (2014);
	Eco-innovativeness	Gilsing et al. (2008) ; Wang *et al.* (2012) ; Arena et al. (2018) ; Arranz et al. (2019) ;
	Digital measurement tools	Husgafvel et al.(2018); Winder and Bobar (2018);

3.4 Framework introduction

According to Taddeo, Simboli and Morgante (2012), an IS network interconnect actors from companies and public organizations to receive mutual benefits by operating in collaboration. The theory sections of this study represented a concrete research field on IS process development with structurization of the IS ecosystem actors and the diverse driving and inhibiting factors impacting the organization process. Although the concept of IS was first mentioned by Ehrenfeld and Gertler (1997) to replicate the natural ecosystem approach in industrial settings, yet the practical implication of the concept is still in the development phase (Gibbs and Deutz, 2005). This research mainly focused on studying the IS system which are organized in collaboration with public and private sector organizations broadly recognized as EIP (Cote and Cohen-Rosenthal, 1998). The literature review presented earlier resulted in formulating a theoretical framework to understand the emergence process of an IS network by collaborating actors, represented in Figure 4.

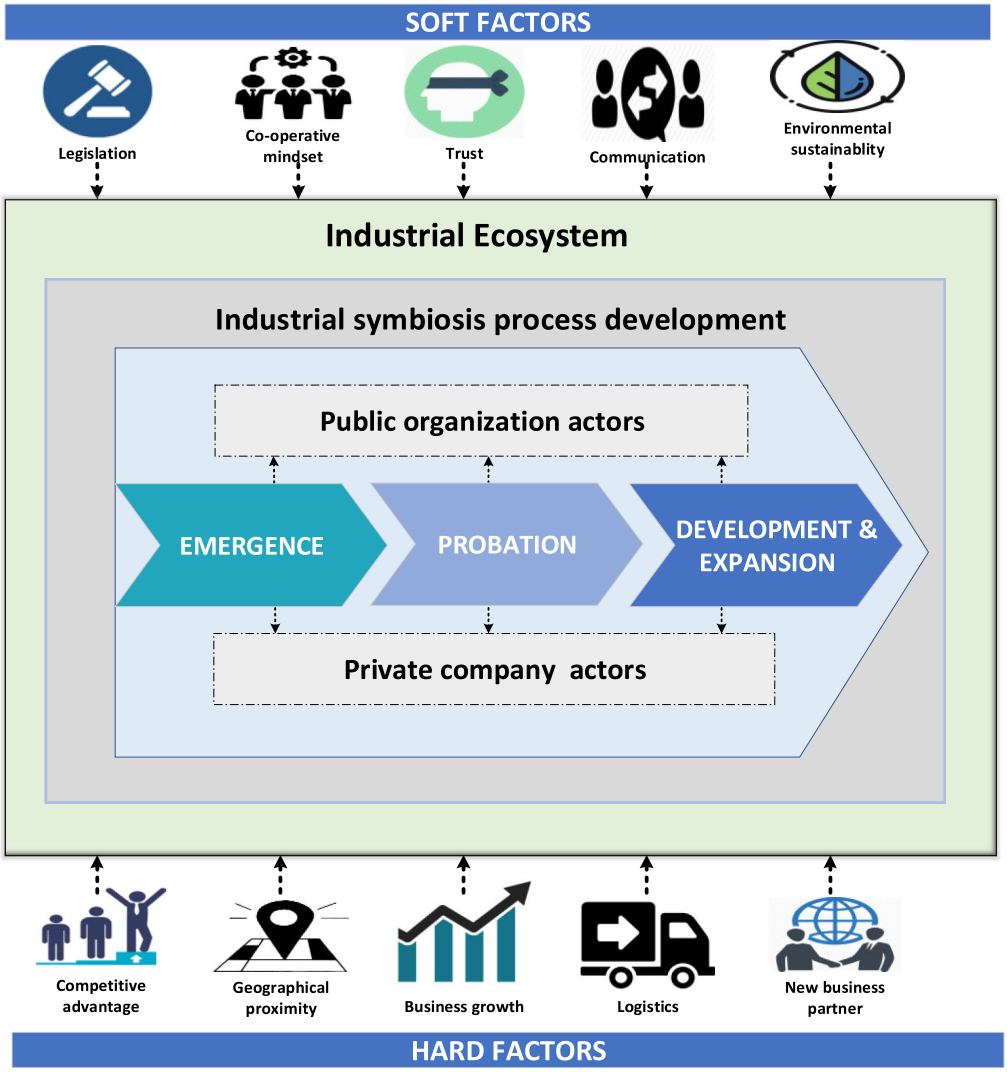

Figure 4. *The theoretical framework of IS process development with emerging drivers & inhibitors affecting the ecosystem.*

As illustrated in figure 4, the IS development approaches through a three-stage process with the collaboration of actors from different organizational systems (Chertow, 2007; Doménech and Davies, 2011; Boons, Spekkink and Jiao, 2014; Walls and Paquin, 2015). Based on the literature review on characteristics of actors present in an IS ecosystem, it can be argued that an IS ecosystem actors engage in collaboration from two sectors: public organization actors and private company actors. The actors involved from these two sectors need to constantly interact with each other at the consecutive phases of the process to form the industrial ecosystem (Pellenbarg, 2002). The public organization actors specifically local governments play the central role in the emergence phase of an IS process (Taddeo, Simboli and Morgante, 2012) while the presence of company actors is merely visible at this stage. Yu, De Jong, and Dijkema (2014) categorized the activities

occurring at the different phases of an IS emergence as institutional, technical, informational, and company, while the actors involved from these two different sectors are mainly responsible for organizing those activities.

The actors engaged from public organizations are mainly comprised of regional authorities such as local governments, municipality actors, environmental agencies, local residents, media (Lowe, 1997). The key incentive of public organization actors in developing the IS structure can be defined as improving the environmental and economic performance of the region (Pellenbarg, 2002). Some of the actors specifically, local and regional governmental authorities are mainly responsible for institutional activities such as implementing policies for cleaner productions (Herczeg, Akkerman and Hauschild, 2018), regulations, monitoring, and evaluating the progress (Geng, Haight and Zhu, 2007). Public organization actors consider IS as a viable way of bringing environmental sustainability (Taddeo, Simboli and Morgante, 2012) while private company actors engage in collaboration with business motives (Roberts, 2004). Each actor present in the industrial ecosystem share a distant vision of participation, yet there needs to be alignment on motives to conduct interdependent activities (Ingstrup, Aarikka-Stenroos and Adlin, 2020).

Private company actors are the core of the operational functions of an IS system (Yu, De Jong and Dijkema, 2014). The collaboration level of company actors for operative processes becomes noticeable at the early probation phase and remains dominant throughout the development and expansion phases. Individual actors engage in business relationships with other actors in the area, with the purpose of achieving cost-effectiveness, sharing information on production activities (Roberts, 2004). However, evolution in the industrial ecosystem is a common phenomenon, the structure of actors will be evolving throughout the entire process of development. Thus, the evolution process of an industrial ecosystem is accompanied by the public organization and company actors' collaboration, where the driving and inhibiting factors are continually emerging and impacting the overall advancement of the IS system.

The process development of an IS system is impacted by diverse driving and inhibiting factors, which are represented in two separate boxes in figure 4 under soft and hard factors. As described earlier, the soft factors are the ones that indirectly impact different activities of an IS system. The public organization actors can be considered as the main originator of the soft factors or might have emerged along the process. Mostly, the public organization actors can be the enforcer of soft factors that will impact the organization of the whole industrial ecosystem. Whereas the hard factors are directly linked to the organization of different process development activities. Thus, these factors are mostly

associated with private company actors. In other words, the hard factors from economic and technical sites like transportation facility, cost reduction opportunity, probability of gaining competitive advantage can either drive or inhibit company actors to participate in the collaboration. Even these driving or inhibiting factors might emerge along the eco-system development process while actors from different levels are interacting with each other.

4. RESEARCH METHODOLOGY

This research work aims to identify the process of developing collaboration to create an industrial symbiosis (IS) system, recognize the different actors involved in the ecosystem, and diverse driving or inhibiting factors impacting the evolution process of the IS system. The research methodology exploited to address these research goals will be comprehensively discussed in this chapter. The first section of this chapter discusses the adapted research design to conduct the analysis. The second section provides arguments behind the selection of cases with a brief overview of the chosen cases. The third section mainly specifies the research data collection methods, data types, and data sources; following that the last section broadly discusses the data analysis method.

4.1 Research design

Gummesson (1993) mentioned the “case study” research method as a strategy to better understand the complex evolution phases of business entities. Case study research provides the opportunity to analyze a contemporary paradox in detail and real-life context to get a pragmatic viewpoint. Hence, the objective of this research work is to get a pragmatic view on *how the collaboration process advances towards the creation of an industrial symbiosis structure over time and what are the effects of diverse catalyzing or inhibiting factors in this ecosystem evolution process*. Therefore, a case study as a research approach was assumed to be well-fitted to meet the research objectives. Case study research can enlighten the investigator with numerous facts and building up connections on those facts results in unleashing the complex phenomena of any process development (Chetty, 1996). However, the research objectives should be clearly defined prior to the empirical studies, and the objective needs to be strictly maintained in the overall research approach (Creswell, 1998). With the selection of case studies as the main research method, this study planned to conduct analysis on multiple cases. Multiple case study methods strengthen the chances of avoiding unexpected outcomes compared to the single case study method as it includes the opportunity of analyzing each of the cases from several dimensions (Yin, 2003). Along with that multiple case studies enable researchers to study cases within the individual case set-up and across set-up (Baxter and Jack, 2008). However, this research particularly chosen multiple case study method to explore IS cases from different regional settings to have an overview on how IS systems are organized.

Krishnaswami and Satyaprasad (2010) mentioned case study researches can be designed in a variety of ways based on the intention of the study like experimental (e.g. hypothesis, scientific), historical, exploratory, descriptive, explanatory, etc. The research design can include a combination of different methods, for example, research can be initiated with an "exploratory" approach by keeping in mind a broader perspective to get preliminary results (Zainal, 2007) and next, move toward a "descriptive" approach to define a specific objective that will provide the researcher a scope of analysis from different dimensions, and contribute to theory development (Krishnaswami and Satyaprasad, 2010). The literature review on IS highlights the fact that limited researches have been conducted on the organizational process perspective of IS systems. Therefore, this research design included a combination of an explorative approach, to identify the pattern of IS evolution and a descriptive approach to recognize the IS ecosystem actors, driving or inhibiting factors though case story (Krishnaswami and Satyaprasad, 2010). Following a descriptive and explorative way of analysis, this research further progressed with a processual approach to recognize the changes process occurring at different phases of an IS system (Dawson, 2014). A processual approach toward case analysis will assist the determination of different critical incidents, activities, the sequence of events that assisted the overall development of an IS ecosystem (Pettigrew, 1997).

Although case study researches can endeavor both quantitative or qualitative way of collecting research data; yet based on the main research questions the qualitative approach was the most suitable one to collect data for this analysis (Yin, 2003). Besides due to the presence of multiple actors in an IS ecosystem, a qualitative approach will mostly suit the research interest as it involves the opportunity of analyzing a wide array of data (Chetty, 1996). Additionally, one part of this research study is focused on contributing to the theory development of the emergence process of IS systems. Campbell (1975) referred to the multiple case study method as a prominent way of developing a robust theoretical structure by creating a bridge on a pool of real-life information. Multiple case studies will enable collecting data on different success factors to understand the synthesized pattern of IS and contribute to theory development based on those empirical data (Eisenhardt, 1989). Furthermore, the adoption of a processual approach (Dawson, 2014) toward investigating the cases will require analyzing data from history, identifying incidents during the emergence process, and finally comparing cases to recognize the pattern (Pettigrew, 1997). Multiple case study approach will enable the researcher to identify the emergence pattern of different cases and a comparison of cases can provide an overview of the factors which functioned positively. Thus, the multiple case study

method with a processual analysis approach is chosen to meet the research objective of understating the collaboration process toward IS.

4.2 Case selection

The selection of interesting and insightful cases is a crucial step to answer research questions and meeting pre-determined research objectives. The literature review presented in chapter 3 indicates that the process development of an IS can be investigated from a wider landscape. It can be studied from an organizational level viewpoint or the diverse operating processes happening in the network, or even can be analyzed from the diverse stakeholder perspective involved in the network. Therefore, before the selection of cases, the aspects to be studied need to be narrowed down and specified. The case evaluation method adopted in this study will be a “focus on priority” approach (Patton, 2003). In this approach, the research questions are formulated by fixing some key aspects such as identification of critical incidents arising over time in the evolution phases of an IS system, who are the actors and key actors involved in the structure, and the drivers and limiting factors of organizing such arrangement. While evaluating the cases the prioritized aspects will justify the selection of cases.

Cases to be studied for this research were selected according to a “purposeful sampling” approach (Patton, 2003). The rationale behind choosing the purposive sampling method is to ensure the selection of an information-rich case with the presence of versatile actors to be interviewed and accessible data sources. Such an approach will assist the investigator to reach the research objectives with in-depth analysis. To comprehend the emergence pattern of a complex multi-actor ecosystem scrutinizing critical cases will be most valuable. Critical cases result in generating logic that can be applied to similar other cases. Hence, the critical cases to be selected need to include some specific criteria according to the research perspective (Eriksson and Kovalainen, 2011).

The first criterion for selecting cases is the presence of public-private collaboration levels. The cases should demonstrate the collaboration process of actors from public and private sectors for IS development over time. This work focuses on identifying the success or limiting factors in the emergence process of IS, to be implicated in IS system development in other set-ups. Thus, the second criteria are to select critical cases that already established linkages and nationally significant. Alongside, the IS network includes an ecosystem approach by involving multiple actors that need to be interviewed to understand their viewpoint. Thirdly, the case needs to illustrate a set of success or limiting

factors that driven or inhibited the progress of network development at the public organization and company collaboration. Most importantly, the collaboration process needs to be organized around bio and circular economy practices.

Interviewing multiple actors is important in an IS set up as it will enlighten the researcher with hidden complex facts, the contradictory perspective from different actors, and the overall development process in a real context, a realization of the difference between expectation and outcome (Yeung, 1995). Those actors can be selected through the snowball approach (Jarre *et al.*, 2020), suggestions for actors who can be more relevant for the research purpose can be collected from other actors involved in the value chain. However, the interviews need to be constructed by prioritizing the key aspects of research to get distinct perspectives from actors to be interviewed. Both of the above-mentioned methods are well suited for qualitative analysis and the rationale behind choosing those approaches is that the purposeful sampling method will guide the selection of an insightful case while focusing on the priorities approach will justify the case selection.

Two nationally significant IS cases from Finland: ECO3 and Envitech match with the above-mentioned case selection criteria impeccably. Both ECO3 and Envitech are organized in the form of an EIP by following IS approach. The ECO3, bio and circular economy business platform initiated it's journey in the Kolmenkulma area in the city of Tampere while the Envitech growth park has been established in the Forssa sub-region. Both of these symbiotic arrangements have evolved through the collaboration of actors from the public and private sector meeting the first criteria of case selection. ECO3 has been recognized as a forerunner of CE business in Finland by Finnish innovation fund SITRA (Kallio, Ermala and Seppänen, 2019), which reflects the selection of a critical case. The ECO3 platform includes multiple actors from diverse industrial fields by making it a complex case to collect data. However, the ECO3 business area is still in the development phase while the Envitech IS system in the Forssa sub-region is functioning successfully for a long time. Preliminary findings on the Envitech system represent the involvement of public and private sector organizations. Although the industrial actors of Forssa operating for a long term in co-operation with each other, yet it is one of the less recognized systems. Thus, the Envitech system offers a broader opportunity to be researched to recognize the success pattern. Both of these critical cases include uncertainties and complexities which can be analyzed to find a promising result to support circular economy business development with the initiation of IS network.

4.3 Data collection

Data collection for qualitative case study analysis can be performed in a variety of ways such as interviews, observation, questioner surveys, or even can be a mixture of different ways to get a pragmatic view of the complex nature of the cases in-depth (Gummesson, 1993). The nature of an IS process development includes multiple actors and requires the collection of historical data to understand the evolution process of the system (Yu, De Jong and Dijkema, 2014). Historical event data that aided the collaboration processes for symbiosis is collected from secondary data sources (Adams, 2012). During the initiation phase of the research, preliminary data related to the case studies was tracked down by browsing through the company websites, media reports, workshops, blog posts to ensure the significance of the cases to be studied and obtain a glimpse of real-time scenario happening in the cases.

The most convenient way of obtaining qualitative research data is performing face to face interviews with the actors involved in the processes to comprehend their actual motivation or feelings about the cases (Adams, 2012). The IS development process requires sharing views, trust among diverse actors that needed to be interviewed to realize what critical events aid the emergence of the system, and collecting data on the driving or inhibiting factors in a real-life context. This research work utilizes both primary and secondary data sources for both the IS cases to be contemplated. The different data sources utilized in the ECO3 case study are presented in Table 3.

Table 3. *Data sources and amount of data on the ECO3 case.*

Data type	***Data source***	***Amount of data***
Primary data: Interviews	Interviewing key responsible persons for platform development.	9
Secondary data:		
Blog posts	ECO3 news archives and blog posts	11
Media	Company websites, Marketing videos	8
Slides	Company presentation slides	3
Reports	Thesis	2
	Case company reports	3
	Research institute reports	2

To recognize the collaboration process development of an IS system, first the nationally significant public-private collaboration platform, ECO3 was investigated. With basic ideation from the ECO3 case, another less recognized yet well functioning IS case the Envitech system was further analyzed. Both primary and secondary data sources were utilized to evaluate the cases. The interview data for the ECO3 case were collected between December 2019 to January 2020 while interviews for the Envitech system were conducted from June 2020 to September 2020. Following the approach of case study analysis, all the research data were collected on a real-time basis and retrospective. For the ECO3 case study, the main data source was the top management interviews as the system is still in development, whereas the study of the Envitech system is strongly supported by both interviews and several case study reports by renowned organizations. The main data generating techniques and data type for the Envitech system is outlined in Table 4.

Table 4. *Data sources and amount of data on the Envitech case.*

Data type	***Data source***	***Amount of data***
Primary data: Interviews	Interviewing key responsible persons involved in the Envitech system.	7
Secondary data:		
Media	Company websites, Marketing videos	10
Slides	Company presentation slides	8
Reports	Thesis	1
	Organization reports	4
	Research institute reports	2

4.3.1 Interview data

Interviews are the most common phenomenon of empirical data collection for qualitative case studies (Mary L. Tucker, Powell and Meyer, 1995). To acknowledge the collaboration process development of an IS system requires identifying the right persons involved in the system for a long time. Alongside this, the IS ecosystem comprises multiple sets of actors from diverse organizational sectors. Hence, to acquire a complete picture of the different perspective of the actors involved in the system, the actors to be interviewed was preliminarily chosen by following a purposeful sampling method. Pettigrew (1997) also mentioned interactive interviews as the most suitable method for processual case

study research. Specifically, face-to-face interviews enlighten the researcher to collect in-depth knowledge and the gesture, posture of the interviewee can reveal his actual though on the process (Gummesson, 2017).

Hence, the most important part is spotting the right person to be interviewed, and for this research, the interviewees were selected by following some pre-determined criteria. EIPs are organized by actors from the public and private sector and the varying institutional logic imparts a significant toward the development of the system. In addition to that, an EIP ecosystem comprises of some key actors recognized as “anchor” companies whose role is the most important in IS system development. Thus, the first criterion was to select actors both from the public and private sector organizations, prioritizing the actors functioning as an anchor company. Apart from that, a similar set of actors were chosen from both of the ecosystems with the purpose of case comparison. Although, the primary set of actors was selected based on the researcher's understanding, yet a snowball approach was further utilized to confirm the accuracy of actor selection and reach out to more potential actors. Moreover, the majority of interviewed actors belong to the top management authority of the company making it difficult to gain access to them. Hence, the snowball approach of utilizing the recommendation of one interviewed actor to gain traction of the other top managers was really helpful in this research.

The interviews were conducted rather in a formal and semi-structured way suitable for explorative case study research (Myers and Newman, 2007). In a semi-structured interview, the researcher gets the opportunity to improvise the question if required based on the actual context. A highly interactive, open-ended interview will generate more knowledge of the cases. The interview questions were grouped into a thematic manner in coherence to the proposed research objectives. Yet, the thematic interview question pattern also provided flexibility to the interviewee to get acknowledged with the research theme broadly. If mentioned the prepared set of interview questions was sent to the interviewee earlier so that the person is aware of the topics, leading toward a fruitful discussion. The interview theme broadly covered topics like the emerging story of the IS with an indication of milestones, the actors involved in the ecosystem, and finally, the driving and inhibiting factors of the IS system development. The interview questions are added in Appendix A. As recommended by Gummesson (2017) notes were taken during the interviews which led toward more efficient discussion with the interviewee. Nevertheless, the interviews were later transcribed by the researcher in actual form, to utilize more enriched substantive data for research purposes (Gummesson, 2017). The main source of data in this research was the interview with different actors.

All the interviews were covered by the researcher alone for both of the cases. For the ECO3 case study, most of the interviews were held face to face in the actor's own organization premise. While for the Envitech study, it was difficult to organize a physical interview due to the Corona pandemic, rather most of the interviews were held virtually. The virtual interview limits the scope of the data collection to some extent, yet not posing any significant challenge, rather saved the time and cost of travel. The interviewed actors in both the ECO3 and Envitech cases are summarized in Table 5 and Table 6 respectively.

Table 5. *Interviewed actors for the ECO3 case.*

Organization/Company	**Organization type**	**Person responsible**	**Position**	**Date and time**	**Interview key insights**
Tampere University	University	Marko Seppänen	Professor	20.11.19, Tampere University, 40 min	Present condition of the project, key actors
Verte Ltd.	Platform development company (publicly owned)	Sakari Ermala	CEO	12.12.2019, Tampella, 60 min	Key actors, main challenges, companies to contact
Pirkanmaan Jätehuolto Oy (PJH)	Regional waste management company (publicly owned)	Harri Kallio	Managing Director	13.12.2019, Tampella, 40 min	Company operation process & what to be implemented in ECO3
Pirkanmaan liitto	Regional public organization	Hannele Tiitto	Project Manager	18.12.2019, Tampella, 40 min	Barriers to digital solutions
Molok Ltd.	Local private company	Jenni Rahkonen	Circular Economy Specialist	20.12.2019, Nokia, Molok factory, 70 min	Challenges of collaborating with public sector, pilot projects
Ecolan Ltd.	Local private company	Jenni Nurmi	Head of Infra business	8.1.2020, ABC Nokia, 52 min	Public sector challenges
ELY-keskus	Regional public organization	Irina Simola	Specialist, bio and circular economy	9.1.2020, Attila, 52 min	Waste reporting system, Waste legislation
Business Tampere	Regional business and development company	Pirkko Eteläaho	Project Manager, Circular Economy	20.3.2020, Virtual, 45 min	Expectations from ECO3
City of Nokia	Municipality	Mikko Nieminen	City Development Director	22.6.2020, Virtual, 41 min	Incentives of ECO3 initiation
		Tiina Laakkonen	Business Director	24.6.2020, Virtual, 45 min	Economic benefits from ECO3

Table 6. *Interviewed actors for the Envitech case.*

Organization/Company	Organization type	Person responsible	Position	Date and time	Interview key insights
Häme University of Applied Sciences (HAMK)	University	Harri Mattila	Adjunct professor	19.05.2020 Skype, 75 min	Present condition of the project, key actors
Suomen Erityisjäte Oy	Part of LHJ group	Jukka Manskinen	CEO	03.06.2020, Teams,43mins	Operative process
Loimi-Hämeen Jätehuolto Oy (LHJ group)	Municipal waste management company	Immo Sundholm	CEO	05.06.2020 Teams, 50 mins	The evolutionary story
FYKKI	Business development platform (publicly owned)	Timo Kärkkäinen	Business Developer	15.06.2020, Teams, 38 min	Business networking opportunity
City of Forssa	Municipality	Antti Heinilä	Technical Directors	17.06.2020, Teams, 37 min	The role of city actors, future plan and policies
Envor Group	Private company	Juha Strandberg	Managing D director	07.08.2020, Teams, 41 min	Individual company role
Saint-Gobain	Private company	Olli Saarenko	Plant Manager	26.08.2020, Teams,50 mins	Role of distant ecosystem actor

4.3.2 Secondary data

Following the nature of a case study research, it is quite obvious to utilize multiple sources for collecting research data (Dooley, 2002). Although the main research data is collected by following a specific way, yet secondary sources of data are utilized to enhance the reliability and validity of the collected data. Alongside Chetty (1996) proposed that collecting research data from multiple sources will suppress the possibility of misinformation will rather develop concrete theoretical findings. Generally, the secondary data for qualitative research is mainly collected from different data archives mostly found via the internet (Hox and Boeije, 2004). This research also compiled secondary from multiple sources like case reports, case company blogposts, media reports, company presentations, company videos, business journals, reports by business development companies, media, newspapers, business magazines, thesis papers, individual company actor websites, IS system website, etc. Nevertheless, the crucial step is finding the most relevant data on cases as the internet is overflown with information and might require searching through important keywords. Secondary data are the most suitable to have a preliminary understanding of the case (Miller and Brewer, 2004), which is beneficial to modify interview questions and can lead toward an in-depth conversation with the actor. Although,

sometimes secondary source might provide biased, yet it can be validated by primary data. Hence, the utilization of different secondary data well suited the purpose of this research study.

4.4 Data analysis

Eisenhardt (1989) mentioned that cross-case analysis is an impactful way to analyze research data in a multiple case study method. This provides the researcher an opportunity to analyze individual cases from theoretical perspectives, afterward comparing different dimensions of each case always results in generating new knowledge. Nevertheless, the research data need to be analyzed in a structured way to conduct a thorough analysis of the similarities and distinctive feature of each case (Baxter and Jack, 2008). This research utilized interviews with ecosystem actors as the main data source. The interviews were recorded with the permission of the interviewed actor. The first step of the data analysis begins with transcribing the recorded information, notes were taken on remarkable points during interviews. Neverthless, prior to each interviews a prelnimniary data analysis were conducted with secondary sources which was further validated during discussion with the interviewed person. Besides, utilization of a wide variety of data sources provided the opportunity of ensuring data relaiblity through triangulation (Farquhar, 2013). Triangulation is a common phenonmenon in case study research to intensify the research findings with validation to create new knowledge.

The transcribed data were further categorized mainly into three sections by following the research questions. Eisenhardt (1989) mentioned that there is no specific pattern to analyze the researched data in qualitative case studies. Still, the researcher can generate insightful information from the cases by preparing a descriptive analysis. On the other hand, Dooley (2002) mentioned a thematic analysis toward analyzing qualitative research data. Following this method, the empirical data from different sources were subthemed into three datasets to specify the underlying pattern. Systematically, the transcribed research data were further coded and tagged according to the key research questions. Both inductive and deductive approach was explored to get a broader viewpoint from the transcribed interview data of ecosystem actors. All the coded data were double-checked to maintain the data coherency and avoid misinterpretation.

To answer the first research question a critical incident mapping technique was followed. In this way, the research data is analyzed inductively where the interviewed actor builds up the storyline of the case, highlighted the milestones from their perspective (Bott and Tourish, 2016). The critical incident mapping technique has been recognized as the best way to understand the case storyline and organizational process of any system. In this

research the critical incidents are defined as the events or activities that happened throughout the process development of an IS system and positively impacted IS system development. Along with primary, secondary data sources mainly blog posts, media reports were utilized to mark the critical events.

Furthermore, the second research question was answered through the identification of the ecosystem actors primarily from the case company websites and descriptive reports on the case ecosystem. Afterward, each actor present in the case ecosystem were categorized according to their role in the IS system and their individual organization type (public or private). The labeled ecosystem actors were visualized by using a network mapping software Kumu. The data related to different actors' expectations, motivation, and varying perspectives on IS system development from both cases were also recorded in detail and categorized following a systematic approach. Lastly, the driving and inhibiting factors impacting the organization of an IS system were identified by following an inductive and deductive way (Miller and Brewer, 2004). During the interview session, each actor was directly asked what factors they consider as drivers or what were the main challenges faced by them during the overall development of the IS system which represent the inductive way of analyzing data. On the other hand, some driving and inhibiting factors were recognized deductively based on the researcher's understanding of the theoretical findings and implicating that on empirical data. For example, “geographical proximity” as driving factors was deductively identified as it was not directly mentioned by any interviewed actor as a driving force. Primarily the driving and inhibiting factors were analyzed to categorize those in different levels following the theoretical findings, and it was also mentioned how the driving or impeding factors function.

The most common phenomena of analyzing research data in a multiple case method are cross-case analysis. Eisenhardt (1989) suggested an efficient way of case comparison is scrutinizing data in a diversified way and then defining some key dimensions based on which the cases will be compared. In this analysis, the research data on both of the cases were collected according to the three key research questions, afterwards, the data on each case was achieved following that three key themes. Therefore, the dimensions for case comparison were also defined under the key research themes. Subsequently, it will provide an in-depth analysis of different distinctive and similar features of each case. Cross-case analysis probes the opportunity of theory development by ensuring the reliability and accuracy of data. In the end, the key findings from individual cases and case comparisons broaden the opportunity of theoretical development.

5. RESULTS

This chapter will introduce the results actualized from studying two different industrial symbiosis (IS) cases: ECO3 and Envitech. Both ECO3 and Envitech are organized in the form of an eco-industrial park (EIP) and established following the approach of IS. Hence, section 5.1 and 5.2 introduces the IS system for both of the cases by highlighting the operating processes of the business area. Next, the sub-sections in each case focuses on responding to the three fundamental research questions provided earlier. The first research question analyzes the collaboration process development of the IS platform with the identification of critical incidents and activities that assisted the advancement of the system. The second research question mainly investigates the ecosystem of the IS, with analysis of what group of actors are involved, what is their key role in organizing collaborations to develop the platform, and what are the main motivations and expectations from participating in the collaboration. Finally, the last research question categorizes the driving and inhibiting factors impacting the collaboration process development of the IS system.

5.1 Case 1: ECO3 system

ECO3 is a publicly funded planned bio and circular economy IS model, sited in the Kolmenkulma eco-industrial park of the Pirkanmaa region, Finland (Moodie, Salenius and Leino, 2019). The Kolmenkulma eco-industrial zone is exclusively located centering around three big cities of the Pirkanmaa region: Nokia, Tampere, and Ylöjärvi and within a 180 km distance from “Helsinki”, the capital of Finland (Ermala, 2020). Considering the industrial heritage of the Tampere metropolitan area and prime location of the Kolmnekulma eco-industrial zone it has grown recognition as the “Finnish growth corridor” (Kallio, Ermala and Seppänen, 2019). As part of this widely recognized cleantech zone, the ECO3 business area is being developed since 2013 on 120 ha areas in the city of Nokia part and already established a connection of 28 different sized organizations. The planned ECO3 business model will serve as a circular economy innovation center for the Pirkanmaa region, provide the opportunity to implement cleantech innovations at the industrial scale, and aims to be an international level pilot and demonstration center of bio and circular economy actions (Business Tampere, 2019).

The core business principle of the ECO3 area will function with the creation of IS linkage by collaborating actors from the public and private sectors for different operating process

plants in the area. ECO3 will provide a platform-based service to connect multidisciplinary organizations for the circular innovation ecosystem. The participating organizations in the IS network will share side streams or by-products as primary resources for daily operations to enable the circular flow of materials and energy. The industrial clusters in the ECO3 business model are planned to be formed around four different rotation cycles: nutrient, timber, energy, and technical. The operating process plant layout of the ECO3 platform is depicted in Figure 5.

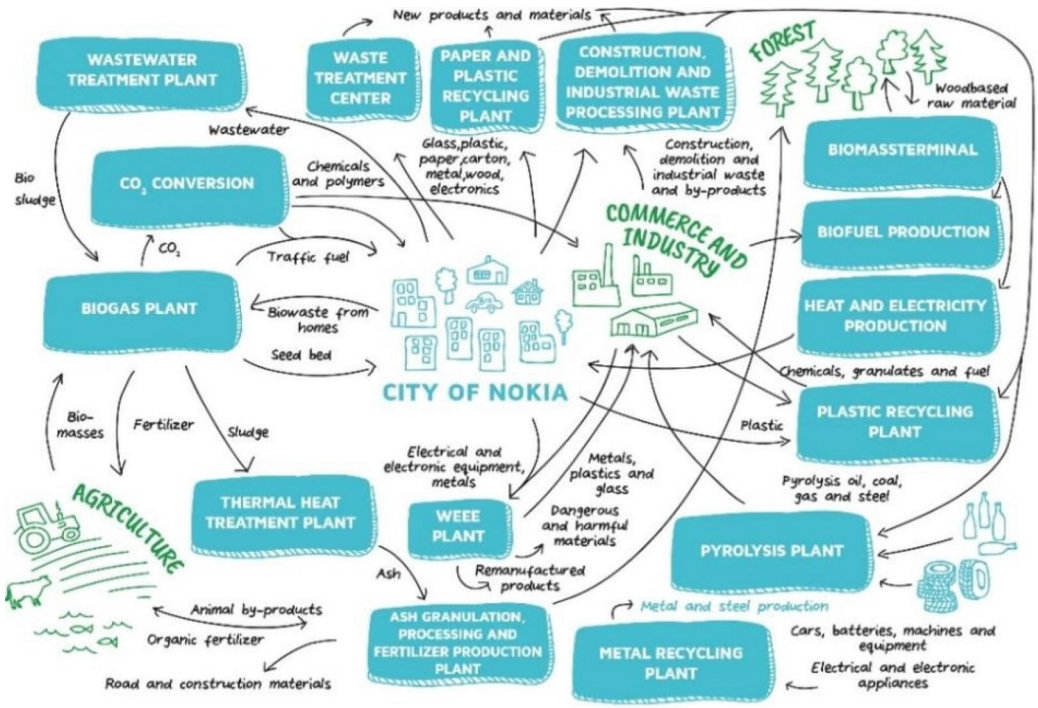

Figure 5. *ECO3 operational concept* (Eco3, 2020a).

The main sources of raw materials for different operating processes will be the wastes collected from numerous sources like agriculture, forestry, biomass, household waste, sludge, metals, plastic materials, ashes, industrial side streams, etc. Nonetheless, the industrial actors integrated into the ecosystem will operate by formulating a symbiotic relationship where one organization's wastes will be converted into another's commodity. In this way the ECO3 platform will ensure reduced use of virgin materials, promote resource efficiency, and the plastics, metal recycling plant will facilitate reuse of the materials. Additionally, the end products are also bio-based products like organic fertilizers, bio-fuels which reduces the emissions and lead toward developing a sustainable ecosystem. Thus, principles of bio and circular economy can be easily recognized in the ECO3 area. The economic benefit received by this ecosystem will be based on reduced

use of natural resources, waste management cost, and will also create employment opportunities in the area.

The ECO3 concept being developed as a joint force by involving industrial actors from the public and private sites, with research organizations, analyzing the market, the platform already gained traction of international actors (Digipolis, 2020). Furthermore, the ECO3 platform includes a huge opportunity of showing how the environmental problem can be solved around the world. Circular economy being one of the strategic priorities of developing Tampere as a smart city, supported the strategic framework development of ECO3. The goal is to work on grass-root actions that would create awareness and lead to a more sustainable way of life for the residents.

5.1.1 The IS process development of ECO3

Following the IS process development phase logic mentioned by Doménech and Davies (2011), the evolution process of ECO3 has been also categorized into three phases: emergence, probation, and development & expansion. With the categorization of the IS process development phases, this section will mainly discuss the activities, development history, critical incidents, or events occurring at the different phases in ECO3 evolution and resulted in developing collaborations to create the ECO3 IS system.

Emergence phase:

During the emergence phase of an IS system primary collaborations among key actors are established with the planning of further co-operation criteria. The ECO3 bio and circular economy business area was inaugurated by the actors from the city of Nokia organically as part of the acclaimed Kolmenkulma eco-industrial zone to introduce eco-efficient operation in the area (Kallio, Ermala and Seppänen, 2019). Nokia city provided around 120 ha area in the eco-industrial zone for business activities of the ECO3 area. The preliminary thoughts of establishing a bio and circular economy business zone was enforced by the national and regional policies developed by the governmental organizations to promote sustainable city development. Furthermore, the city of Nokia beholds a long history of trade and industrial activities which supported the development of the ECO3 business area. To support the goal of developing innovative bio and circular economy businesses the city of Nokia opened a platform operating company specifically for the ECO3 area, named Verte Ltd. (Moodie, Salenius and Leino, 2019). Initially, Verte was solely responsible to arrange collaboration among actors from the public and private sectors with support from regional authorities and arrangement of funding for the infrastructure development.

The conceptual journey of the ECO3 business area activities, started at the beginning of the year 2000, when *Mr. Harri Kallio,* Managing director of *Pirkanmaan Jätehuolto Oy (PJH),* and *Mr. Sakari Ermala,* CEO of Verte Ltd, unified with a dream of "No Landfills" (Ermala, 2020). According to the waste law of Finland, municipal authorities are responsible for administrative functions of the municipal waste management activities. Pirkanmaan Jätehuolto, a non-profit organization from the public sectors has been responsible for solid waste management in the Pirkanmaa region including the city of Nokia. Till now the municipal waste management authority has been able to successfully recover around 90% of the waste as heat and materials. Finnish law of encouraging residents and industrials to sperate waste (lowered waste dumping fee) at the source has strongly supported the waste management activities of PJH. Alongside, PJH strategized to respond to governments' actions of moving toward a circular economy from the linear economy model and the ECO3 business area seemed to be a great opportunity for such initiatives (Kallio, 2017).

A decision taken by the top management (Mr. Harri Kallio) of PJH to be a bold innovator around circular economy and fighting climate changes was a revolutionary step toward progressing the ECO3 system. The organization decided to invest in the biogas plant in the Nokia ECO3 area by replacing the composting operation in Tarastenjärvi, to bring cleaner energy sources for transportation and industrial activities (ECO3, 2016). At the same time, Nokian Vesi, a waste-water treatment center of the city of Nokia was planning to establish a new water treatment facility in the ECO3 area (Moodie, Salenius and Leino, 2019). The sewage sludge generated from the waste-water treatment facility of Nokian Vesi can be further treated as raw materials in the biogas plant (ECO3, 2019a). Thus, the shared interest of Nokian Vesi and Pirkanmaan Jätehuolto resulted in formulating the core relationships of the network. Since then Verte and Pirkanmaan Jätehuolto has been performing as a joint force to initiate the collaboration process development for the ECO3 system through participating in different events. Following the dream of no landfill, an advanced collaboration model "public-private-people-partnership (4P)" was proposed around the circular economy business to fight climate changes in the ECO3 area (Kallio, Ermala and Seppänen, 2019). The process development phases of ECO3 symbiosis model with the critical incidents are remarked in Figure 6.

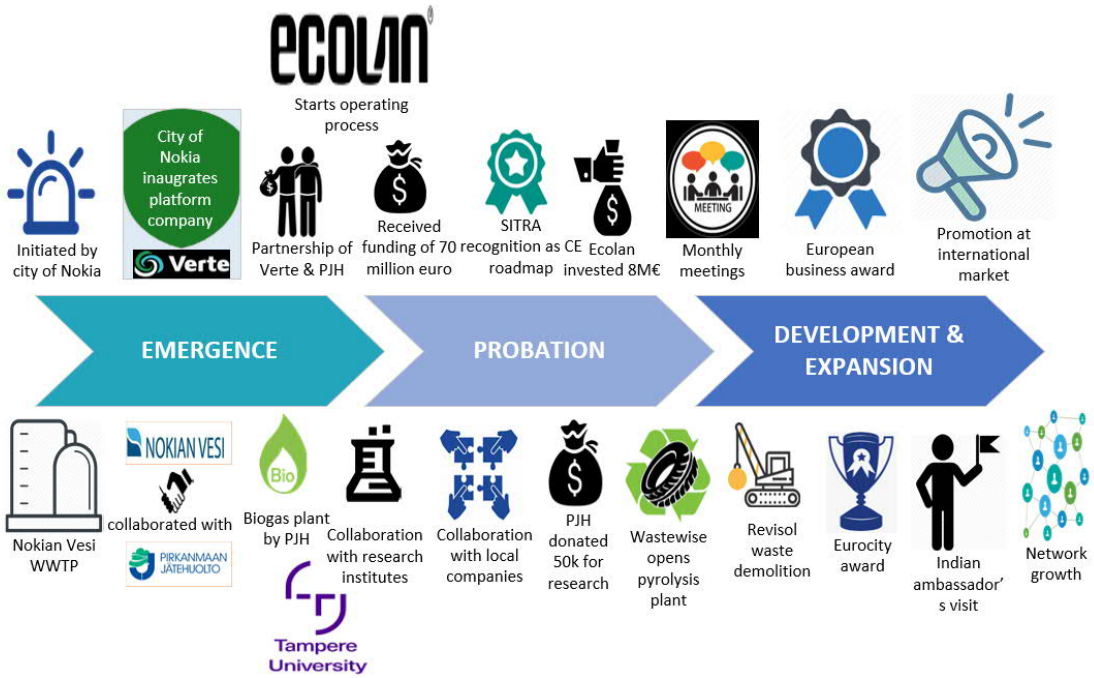

Figure 6. *ECO3 IS development phases with critical events.*

Probation phase:

With the establishment of core relationships, the ECO3 system entered to next phase of IS development. During the probation phase already defined, relationships grew stronger and opened the opportunity for more actors to join the platform. The fundamental surveys and investigation toward creating the IS platform started in the year 2013 to 2014, and within less than four years ECO3 reached 70 million euros in new investment (Moodie, Salenius and Leino, 2019). The goal of the ECO3 area is to support innovations around bio and circular economy activities and experimenting with new ways of using wastes as raw material. To support the innovation ecosystem of ECO3, Verte organized collaboration with research institutes and universities. Alongside, PJH donated 50,000 euros for research activities at Tampere University to support the circular economy innovation ecosystem development of the ECO3 area (ECO3, 2019b).

> *"The university has a lot to offer when waste management in Pirkanmaa is being developed as a pioneer towards better customer understanding and environmental benefits, as well as a better functioning circular economy for society." says Harri Kallio, Managing Director of Pirkanmaan Jätehuolto (ECO3, 2019b).*

Finland's national policy of "carbon neutral economy" and growing attraction toward the circular economy business model vigorously supported the growth of ECO3 system de-

velopment. The Finnish innovation fund SITRA recognition of ECO3 as a roadmap toward the circular economy in Finland undoubtedly increased the value of the platform toward industrial actors (Nokian Kaupunki, 2018a).

ECO3 being recognized as a bio and circular economy business platform, several small and medium-sized companies joined the system at the initial growth phase. Ecolan is the first company from the private sector to start operating in the ECO3 area. Alongside this, the company made an investment of 8 million euros for production plants in the business area and planned expansion of the buildings three times in the year 2017 (ECO3, 2017a). However, the fundamental ECO3 concept is established based on collaboration from the public and private sectors.

> *"Private companies have in-depth expertise in their own fields, while public operators have mastered large systems – we truly want to use that as a basis for finding new models that are useful to everyone at ECO3." says Harri Kallio, Managing Director of Pirkanmaan Jätehuolto (Kallio, 2017).*

The industrial actors operating in the bio and circular economy in the city of Nokia mostly joined the ECO3 network at the initial stage. The collaboration process was mainly organized by Verte through informal meetings or gathering at events. On top of everything, the local company actors were eager to get recognized with what was happening nearby. For example, Revisol Oy, a Finnish company with a specialization in circular economy owns a business plant in the Nokia city. Revisol already invested in a waste demolition center in the ECO3 area which planned to operate in the year 2020 (ECO3, 2020b). The corporate waste sorting services provided by Revisol will be a key enabler of further processing of waste materials into energy sources in the ECO3 area smoothly. Another metal recycling plant located in the Nokia city, Tramel also planned to inaugurate a new operating plant in ECO3 by collaborating with other actors since 2018. The company mainly deals with scrap metals and electronic equipment in an environmentally friendly way. Tramel is developing a cutting-edge metal recycling plant in the ECO3 area which planned to operate with full functionality in the year 2020.

In the year 2017, Wastewise inaugurated its production facility in Nokia's ECO3 area by purchasing a tire crushing plant and rubber recycling business operation (ECO3, 2017b). The company constantly develops its operating processes, conducts innovation practices, and introducing new technologies to ensure the growth of its own circular economy business with the advancement of the ECO3 system. Wastewise partnership with Suomen Kiertoketju Ltd. for a pyrolysis plant in the ECO3 system considerably progressed the operating process development of the area. The investment project continued till the

end of the year 2019 and Wastewise will continue to operate in the area by co-operating with other organizations. Thus, during the probation phase of the ECO3 system, numerous small and medium-sized companies operating mostly in the material recycling process joined the ecosystem. The involvement of these actors opened the opportunity for other organizations to join the network, developing trust and co-operation among the existing actors of the ecosystem. The actors involved in the ecosystem gathered for monthly meetings and continually encouraged by Mr. Sakari Ermala to share their business ideas, thoughts, and knowledge to develop the ECO3 system.

Development and expansion phase:

The development and expansion phase can be defined as promoting the ECO3 concept at the international and national levels. The concept of ECO3 public-private collaboration model developed in the Pirkanmaa region, got international recognition with the visit of international actors and winning multiple awards. Moreover, the core actors of the ecosystem PJH and Verte have been disseminating the ECO3 business ideas among other industrial actors, developing marketing materials, and participating in competitions to promote the concept. In the year 2017, the Indian ambassador of Finland paid a visit to the ECO3 area with an invitation from the platform operating company, Verte (ECO3, 2017d). The ambassador's visit in the area was specifically arranged to utilize ECO3 as a bio and circular economy business demonstration center so that the ECO3 concept can be offered in a larger ecosystem like cities in India.

> *"The visit of the Indian Ambassador was one step to raise the profile of the ECO3 region abroad. Our goal is to further expand our region and attract foreign investment and new jobs to Nokia." says Sakari Ermala, CEO of Verte (ECO3, 2017d).*

Top projects of the Indian economy for foreign countries were presented by the ambassador at the event and the strategy of developing business relationships with India was also mentioned. Such a co-operation event with international actors enormously increased the importance of the ECO3 business center for companies to collaborate on the platform. The actors from companies consider ECO3 as a gateway to operate and develop a business relationship with international organizations. Furthermore, promoting the ECO3 concept at the international level is an imperative way of increasing value, reliability, and attracting company actors for collaboration. The ECO3 circular economy business co-operation model from the Pirkanmaa region won the best circular economy operation model award in the EUROCITIES co-operation award series in November 2017 (Nokian Kaupunki, 2018b). The event was organized in Ljubljana, Slovenia, and

around 130 cities and 40 partner cities from 35 countries participated in the program. As referred by during that time,

> *"Success in the EUROCITIES Awards competition brings us wide visibility internationally as well. It shows that long-term cooperation between public and private actors in accordance with the ECO3 concept is relevant and creates genuine business platforms." says Eero Väätäinen, former Mayor of the City of Nokia (ECO3, 2017c).*

To recede the societal challenges that appeared from different industrial activities Europe has set the strategy of promoting innovative, sustainable, and ethical business models. For this purpose, the European Business Award competition is organized every year, by inviting public and private companies from all over Europe (Nokian Kaupunki, 2019b). The best innovative and sustainable business ideas are awarded based on a different category. In December 2019, the joint circular economy business model of Verte and PJH was awarded as the best business model in the social and environmental responsibility category by competing with around 2700 companies in a different category. Winning such a prestigious business award, significantly increased the value of the ECO3 system as a national and international level circular economy business platform. The international recognition by the leading European countries has fortified the ECO3 business platform, drawn more interest of local actors, and recognized as a pathway toward a circular economy in Finland.

5.1.2 Ecosystem of ECO3

The ecosystem of ECO3 integrated a versatile set of actors from diverse industrial fields to organize the bio and circular economy business activities in the area. The concept of Nokia's ECO3 business area is based on cross-municipal collaboration between public organizations with a layer of private sector companies and research institutes in the ecosystem (Kallio, 2017). The actors committed to developing the area mostly belong to three different levels: local, regional, and national co-evolving with each other toward establishing the platform. Local-level actors such as municipalities, waste-water treatment facilities, recycling companies, SMEs have joined the platform and guided the ECO3 system development. Alongside, regional-level actors like economic development institutions, business development platforms, regional waste management organizations, regional councils have been strongly involved in promoting and advancing the project. Furthermore, the presence of national-level actors in the platform is significant to manage funding and reliability of the platform to other actors. As well stakeholders from research organizations are also co-operating in the development of the area by providing

required knowledge for different process development. The actors involved in the ECO3 IS ecosystem is represented in Figure 7.

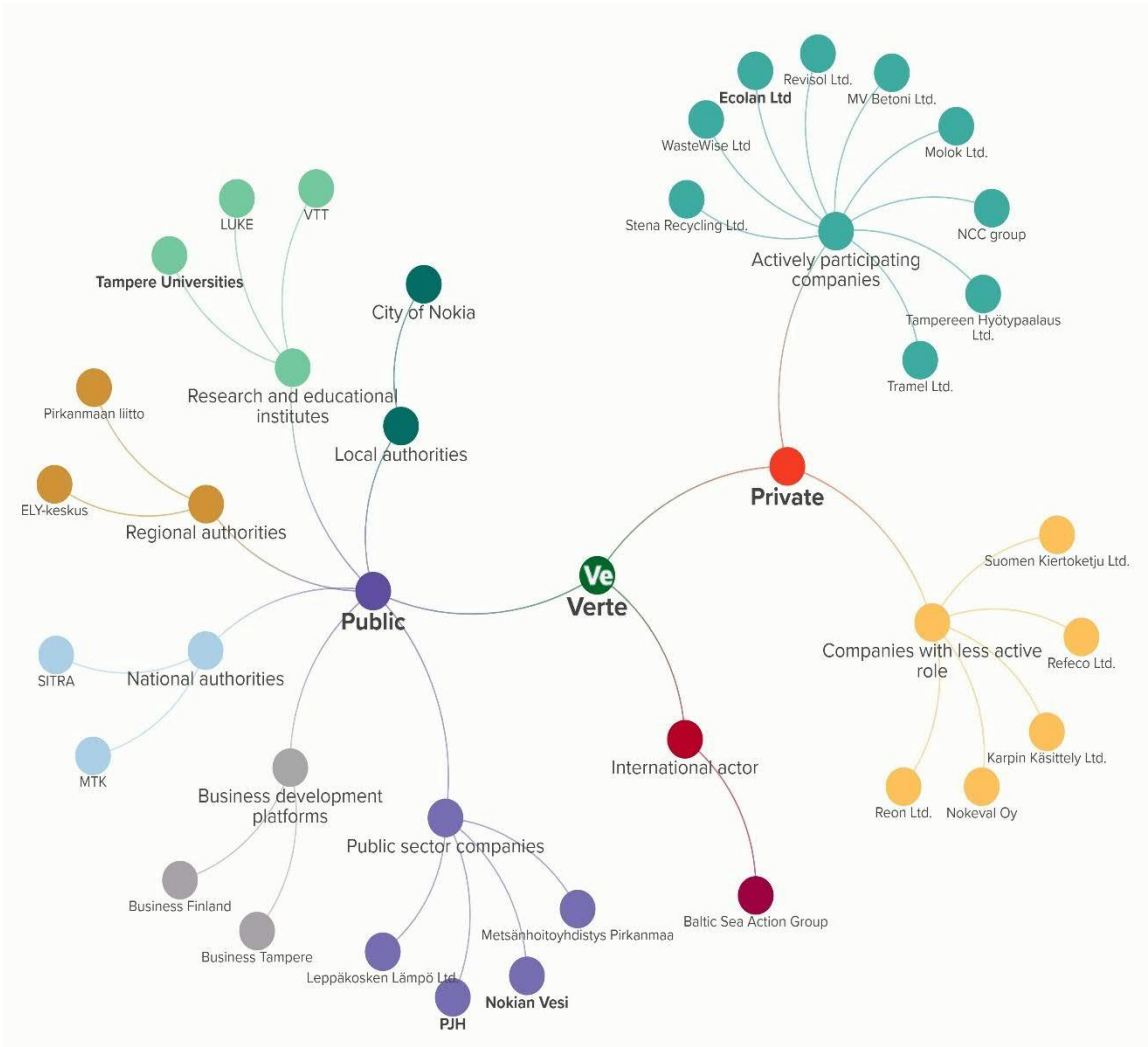

Figure 7. *ECO3 ecosystem actors.*

As illustrated in figure 7 Verte (owned by the city of Nokia) being the main operator of the ECO3 ecosystem, has been kept in central of the figure and functioning as the main linkage creator among other public and private sector organizations. The public sector organizations are mainly comprised of municipalities, business development platforms, educational and research institutes, fund providers. Along with this some regional authorities from the public sector functioning as facilitators to influence private companies to join the ecosystem. The private sector cluster is mainly comprised of companies operating in the Pirkanmaa region and part of the ECO3 ecosystem. The core actors of the ECO3 IS ecosystem has been bolded in figure 7. The later section will explicitly discuss the role, motivation, and expectations of different public and private sector actors involved in the ecosystem. The public organization actors and company actors are further

summarized in Table 7. The organization type of public sector actors is highlighted with gray shade in the table 7.

Table 7. *Public and company actors in ECO3.*

Public organization actors			
Local authorities	***Regional authorities***	***National authorities***	***International actors***
City of Nokia	Pikanmaan liitto	The Finnish Innovation Fund Sitra	Baltic sea action group
	ELY-keskus	MTK	
Public sector companies		***Business development platforms***	***Research and educational institutes***
Pirkanmaan Jätehuolto Oy (PJH)	Metsänhoitoyhdistys Pirkanmaa	Verte Ltd.	Natural Resources Institute Finland (LUKE)
Nokian Vesi	Leppäkosken Lämpö Ltd.	Business Finland	Tampere University
		Business Tampere	VTT Technical Research Center of Finland Ltd.
Company actors			
Ecolan Ltd.	Reon Ltd.	Molok Ltd.	Karpin Käsittely Ltd.
Wastewise Ltd.	MV Betoni Ltd.	Stena Recycling Ltd.	Suomen Kiertoketju Ltd.
Revisol Ltd.	Napapiirin Teollisuushuolto Ltd.	Tampereen Hyötypaalaus	
Tramel Ltd.	NCC group	Nokeval Ltd.	

Public organization actors in the ECO3 ecosystem:

The *key initiatives* for establishing the ECO3 business area were taken by the *public sector*, specifically from the *city of Nokia* who provided necessary funding and required space to set up the business area (Moodie, Salenius and Leino, 2019). The municipal services and educational facilities offered by the local authorities secured the business growth and development of Nokia city (Business Nokia, 2020). Alongside this, city actors are highly committed to supporting its local business communities and offers an excellent framework for its business development. To ensure regional development and economic sustainability the city actors strategized to inaugurate several new eco-efficient business areas and the ECO3 is one of those (Nokian Kaupunki, 2020). The local businesses

around bio and circular economy are highly encouraged by municipal authorities to join the ECO3 system to create a smart and sustainable business ecosystem. Along with the local companies, the city residents are also a significant part of the ECO3 ecosystem. The city of Nokia accredited a platform company, Verte, and assigned a project manager to coordinate and organize the ECO3 ecosystem.

Verte Ltd., the ECO3 platform operating company is owned by the city of Nokia, largely responsible for managing and developing the area. Verte is operated by Mr. Sakari Ermala and can be recognized as the *main operator* of the ECO3 platform. The key role of Verte in ECO3 development is the creation of interlinkage among companies and connecting suitable companies in the area. To reach these objectives Verte is providing platform-based services, arranging meetings, demonstrations, and communicating with actors from different sites to develop the ECO3 area. Verte is also responsible for promoting the area at the international market with participation in several events. To encourage innovations around bio and circular economy Verte is also supporting research institutes and providing scalable business opportunities with innovations from companies in the ECO3 area (Kallio, 2017).

> *"In the ECO3 area, bio- and circular investments will be translated into practical activities in the coming years, making ECO3 business area the best bio-economy and circular economy hub in Finland." says Sakari Ermala, CEO of Verte* (ECO3, 2020a).

Although Verte is currently working with only the ECO3, the core interest of the company is to connect industrial cities from all over Finland. Finnish growth and economy come from industrial cities like the city of Helsinki, the city of Oulu, the city of Turku (Sakari Ermala, Verte). Therefore, Verte is asking those industrial cities to join the ECO3 network to combine information from all those 5 or 6 industrial hub spots, where businesses around CE is already happening. Connecting those cities will ensure business scalability in the ecosystem and manage bigger funding from the government.

> *"I am going to show the idea in Helsinki, first we create the platform with a local mix (industries) in CE in Tampere, then mix the cities, which will be run by Verte. The idea is that these cities can establish their ECO3 platform or join the already established plan in Nokia to create industrial-scale business opportunities." says Sakari Ermala, CEO of Verte.*

Even though Verte is owned by a public organization, the incentive of the company to develop the ECO3 area is economically driven, as it will create more employment opportunities and business opportunities in the area. Alongside, Verte aims to generate profit

by connecting actors and providing required services to the companies participating in the area. Verte strategizes to utilize the ECO3 system as an international pilot and demonstration center of bio and circular economy activities. For example, the ECO3 concept will result in achieving greater value if implicated at larger ecosystems like in cities of India, China, Russia, etc. Therefore, the *main incentive* of Verte is to develop ECO3 as an industrial scale business platform and afterward sell the concept of the "ECO3 business system" in the international market. In the future, the company desires to earn profit by commercializing the ECO3 model and Verte can be directly participating as an agency to the "ECO3 model" development in other countries, or can just provide expertized knowledge in EIP development.

At the initial stage organizations from the public sector Pirkanmaan Jätehuolto (waste management company of the Pirkanmaa region), Nokian Vesi (city of Nokia's water company), Leppäkosken Lämpö (energy company) and, Tampere University (educational institute) worked in close collaboration with Verte as *key anchor* organizations to assist the collaboration and operating process development of the ECO3 business area (Marko Seppänen, Tampere University). However, over the years the structure of the ecosystem evolved with active integration of actors from the private site while some core actors became loosely connected. Figure 8 represents the core ecosystem actors at the initial stage.

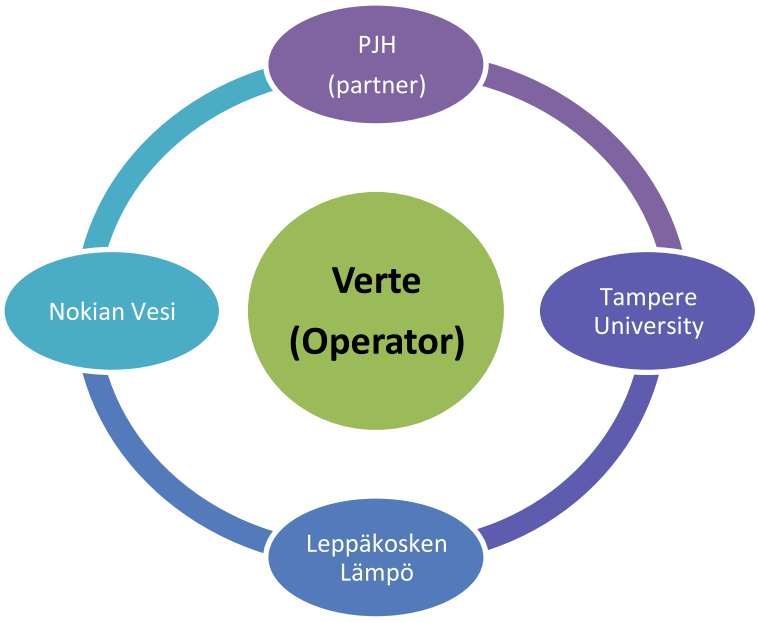

Figure 8. *Core ecosystem actors at the initial stage.*

The core processes of the IS in the ECO3 area initiates with the involvement of actors from the waste management center as the operating concept of the platform includes re-using waste*. Pirkanmaan Jätehuolto*, a public organization owned by 17 municipalities, including 444 000 inhabitants is providing the waste management facility in the Pirkanmaa region. The waste management organization is the key enabler of circular economy activities in the Pirkanmaa region. In the ECO3 area, Pirkanmaan Jätehuolto is joined as a *partner organization* with Verte and taking the leads to arrange collaborations and evolution of the business platform. The operating principle of the organization follows preventing environmental degradation.

Considering national guidelines and policies as a frame, Verte and Pirkanmaan Jätehuoltoare working as a joint force for the development and management of activities in the ECO3 area. The organization has been the central actor of the ecosystem to initiate symbiotic relationships with actors from the public and private sectors in the ECO3 platform. Pirkanmaan Jätehuolto will have a key role in nutrient recycling and waste to energy conversion plants. In addition to that, the company planned a new biofuel plant in collaboration with Nokian Vesi in the area. Nokian Vesi planned to develop a new waste-water treatment facility in the ECO3 area and the bio-facility will handle the sewage sludge from Nokian Vesi. The plant will convert the waste into transport fuel, recycled fertilizers, and soil, and the waste-water generated will be further treated by Noikan Vesi. Pirkanmaan Jätehuolto owns expertized knowledge on infrastructure management and as an anchor company providing platforms to develop new circular economy businesses in the area.

There is a plan of establishing solar panels in the old landfill area, and if there is a cheap energy source available then a private organization will take care of converting CO_2 into methanol to fight the environmental change (some technology available for this but huge probability of new technology). In addition to that, the organization collaborated with Tampere University to fund circular economy innovations to discover new ways of handling municipal and industrial waste, exploiting ways of conducting eco-efficient operations. Hence, the main motive of the company's participation in ECO3 is to minimize the environmental impact through municipal waste management and the creation of examples in bio and circular economy business.

> *“The main vision of Pirkanmaan Jätehuoltoto to participate in ECO3 is to be a bold innovator of thought models to fight climate change and promoting CE globally.” says Harri Kallio, Managing Director of Pirkanmaan Jätehuolto.*

Research and educational institutes:

To support the advancement of the ECO3 business area as a circular economy innovation ecosystem presence of *knowledge-based* organization clusters is of great importance. This particular organization cluster mainly comprises research institutes that perform experiments to identify new ways of using waste, piloting innovations on a small scale to understand the viability of the solution. In the ECO3 platform, research institutes get the opportunity to keep pace with industries, share information on the latest updates, and research requirements. *Tampere University* has been involved in the ECO3 platform since 2014 as one of the *key anchor* organizations (ECO3, 2020). Researchers from the university have been working from the beginning to develop the ECO3 system concept. The university has been conducting researches to provide technologies for waste-water treatment in collaboration with Nokian Vesi and studying the bio-gas plant to be developed with Pirkanmaan Jätehoulto (ECO3, 2020c). Collaboration with Tampere University will be always existing on ECO3, even if the system goes into full production for future research & development.

> *"If we create something with the university, it's not just only knowledge, it's something we develop for the future." says Sakari Ermala, CEO of Verte.*

Along with Tampere University, research institutes like VTT (technical research center of Finland), Natural Resources Institutes Finland (LUKE) are working consistently for ECO3 development. The purpose of research institutes to join ECO3 is not directly connected to the business, rather those are providing insightful knowledge to create new business opportunity around bio and circular economy, for example testing the feasibility of bio-based CO_2 in industrial operations, examining the procedure of solar energy production in the area (ECO3, 2018c). Tampere University's circular economy research develops, among other things, processes that improve energy and eco-efficiency, renew materials, save natural resources, and reduce emissions to the environment. The aim of the study is, for example, to recover nutrients and metals from various industrial and municipal waste and by-product streams. The researchers from Tampere University contributed technological solutions in collaboration with Nokian Vesi for the water purification project and for biogas decomposition in co-operation with Pirkanmaan Jätehuolto (ECO3, 2020c). At the university, research is conducted at the molecular level which is further implemented at a large-scale in the ECO3 area.

> *"The circular economy plays a crucial role in building a sustainable society. The circular economy helps to curb climate change and maintain biodiversity. The university will strengthen multidisciplinary expertise and education related to circular*

economy solutions that support circular economy solutions." says Mari Walls, President of Tampere University (ECO3, 2019b).

The expert research team of Tampere University considers ECO3 as a great opportunity for students to gain practical knowledge. The university has collaborated with the eco-system permanently even after the planned concept gets established and considers the present version as "ECO3 1.0" which can be re-designed for future advancement (ECO3, 2020c). At present, Tampere University is conducting researches from technical perspectives while aims to conduct researches on the social impact of such a platform in the future.

Intermediaries from the public sector:

Along with the core actors from the public sector, the ECO3 ecosystem embraces the presence of regional authorities, and national level organizations that are mainly functioning as influencers to attract company actors. The ECO3 system recognizes these players as "*co-operation partners*" who facilitate different development activities of the ECO3 system. The prime incentives of these stakeholders are to support regional and national level development, create new employment opportunities, environmental sustainability, and promoting circular economy businesses. Organizations from the public sector like the Baltic Sea action group, ELY-keskus, Business Finland, Business Tampere, MTK, Pirkanmaan liitto, and Sitra have been part of the ECO3 ecosystem to influence the creation of the circular economy business at the national level.

Pirkanmaan liitto, the regional development organization of the Pirkanmaa region is strongly involved in the ECO3 ecosystem and participating in different development activities. Although the institution does not possess any legislative rights to force companies to join the platform, hence the policies and guidelines designed by the organization will facilitate the collaboration process development of the ECO3 IS system (Hannele Tiitto, Pirkanmaan liitto*).* On that ground Pirkanmaan liitto has been playing a significant role as an influencer and working in co-operation with individual company actors, encouraging regional municipalities, business organizations, and inhabitants to approach in a collaborative way for the development of the ECO3 area. Pirkanmaan liitto considers ECO3 as a smart and ecological way of handling business operations in the region. The organization has been supporting regional bio and circular economy-based business activities to fight the environmental challenges raised by traditional industrial activities (ECO3, 2020a). Besides, it is playing a vital role by encouraging companies and local residents to co-operate in the ECO3 business activities.

> *"The main expectation from our company to participate in ECO3 is we want to learn from the platform and implement the learnings in other municipality." says Hannele Tiitto Project Manager (Circwaste) of Pikanmaan liitto.*

The presence of actors from the regional-level public organization, *ELY-keskus* in the ecosystem has significantly escalated the value of the ECO3 system to attract private company actors. ELY-keskus is responsible for regional development and different implementation tasks around transportation, economics, and environmental sectors in all over Finland (ELY-keskus, 2020). The circular economy is considered as the strategic development work in the organization and providing different financial aids to small and medium-sized enterprises according to the legislation developed by the government (Irina Simola, Ely-keskus). Therefore, the business concept of the ECO3 area strongly matches the strategic perspectives of ELY-keskus.

> *"ECO3 is a forerunner in Finland especially in the Pirkanmaa region, this work is really valuable for development, establishing the co-operation from the public and private site." says Irina Simola, Bio and CE Specialist from ELY-keskus.*

In Finland, the waste management legislation is formulated by the governmental authority and the environmental department of ELY-keskus is responsible to monitor the companies following their environmental protocols and analyze the waste flow data provided by the companies (Irina Simola, Ely-keskus). The ECO3 system also comprises company actors who are under the supervision of ELY-keskus. To coordinate the collaboration process evolution, ELY-keskus is arranging events and informal meetings to interconnect companies and organizations. The operators who are dealing with the wastes can come into the ELY-keskus and meet with the environmental supervisors to improve their operations and with the actors from the city of Nokia to exchange information.

Moreover, ECO3 being established as an industrial scale business area, multiple business development platforms from local, regional, and national levels are also involved in the ecosystem. For instance, besides the business development platform from the city of Nokia (Business Nokia, 2020), the ecosystem of ECO3 comprises its counterpart from the Pirkanmaa region. *Business Tampere*, the regional economic development agency of the city of Tampere is actively involved in the ecosystem for the advancement of the ECO3 area. The organization is functioning as an intermediary to find industrial actors from the national and international networks to integrate into the ECO3 network, investigating the material sharing opportunities with existing companies of the ECO3 platform (Business Tampere, 2016). The main motive of Business Tampere to join the ECO3 system is to foster economic development in the city of Tampere and the Pirkanmaa

region. The companies operating in the ECO3 area can join the Pirkanmaa regional corporate network (Business Tampere, 2016). ECO3 is considered as an investment point attraction for companies to work in collaboration by forming a symbiotic relationship. The rationale behind joining the ECO3 area was described as following,

> *"ECO3 is the largest cleantech business area in the Pirkanmaa region, the biggest business opportunities in the region are involved in the ECO3 area. It will be an investment point of business growth in Finland." says Pirkko Eteläaho, CE Project Manager of Business Tampere.*

ECO3 platform will create a good example of a circular economy business hub at a national and international scale from Finland (Pirkko Eteläaho, Business Tampere). An interesting point on Business Tampere involvement is that it considers ECO3, an opportunity to trial with clean technology solutions by companies. The innovation practiced at the ECO3 system will attract visitors from the national and international levels which will develop the competency of the Tampere as a "Cleantech" solution provider worldwide (Business Tampere, 2016). ECO3 offers a great operating environment for the industrial actors, the opportunity to innovate and Business Tampere expects to export environmental technologies implicated at ECO3 level to the global market (Pirkko Eteläaho, Business Tampere).

In recent days Finland has gained a strong reputation for cleantech activities and achieved multiple awards for its contribution from the EU level (Business Tampere, 2020). Therefore, Tampere being the second largest industrial city of Finland, "cleantech" is included as one of the strategic policies of Tampere city-regional development. The city already established a competitive ecosystem to innovate cleantech solutions in collaboration with companies, researchers, and experts and ECO3 will open the gateway of achieving practical expertise (Business Tampere, 2019). To that end, the planned ECO3 model will include the largest businesses around the circular economy and will be a sustainable source of economy.

Company actors in the ECO3 ecosystem:

The core of economic activities in ECO3 commenced with the involvement of local business communities in the ecosystem. The ECO3 IS ecosystem comprises many small and medium-sized companies along with actors from multinational companies with a focus on the circular economy, sustainability, and cleantech solutions. This also opens the opportunity of including technology or service providers specialized in bio and circular economy activities in the ecosystem. In the year 2017, Ecolan, a Finnish bio-fertilizer manufacturing company, located in the city of Nokia willingly joined the ECO3 IS platform

(ECO3, 2017a). At the moment Ecolan Oy is one of the key participating organizations from the private sector and already established an ash refinery plant in the ECO3 area. The circular economy is followed as the focal principle in the company and brings out bio-fertilizers, construction materials with the utilization of industrial side-streams. Surprisingly, the operating principle of Ecolan firmly matches with the ECO3 IS concept. ECO3 will provide the opportunity to conduct Ecolan's operation most efficiently. Therefore, the actors from Ecolan are actively involved in the development process of the ECO3 area.

> *"ECO3 is a nice platform to create synergies and we expect to get new neighbors and facilities to be added in Ecolan from ECO3." says Jenni Nurmi, Head of Infra Business of Ecolan.*

Ecolan being an SME considers ECO3 as an attractive platform to create business synergies, experiment with side-streams to bring out new products (Jenni Nurmi, Ecolan). Additionally, ECO3 will permit cost-effective logistics and ensure environmental-friendly industrial operation. However, until now no synergies have been created for the raw materials used in the production plant in the ECO3 area. Yet, the company has been in collaboration with many other industrial actors like NCC, Pirkanmaan Jätehuolto for experiment purposes (ECO3, 2020a). Additionally, in 2019, ELY-keskus (responsible for regional development) has examined the quality of bio construction materials produced by Ecolan (ECO3, 2020a). ELY-keskus agreed that the construction materials manufactured from the ECO3 area will be used for road development in the Pirkanmaa region. The evolution of core ecosystem actors in terms of active participation in IS process development activities is shown in Figure 9.

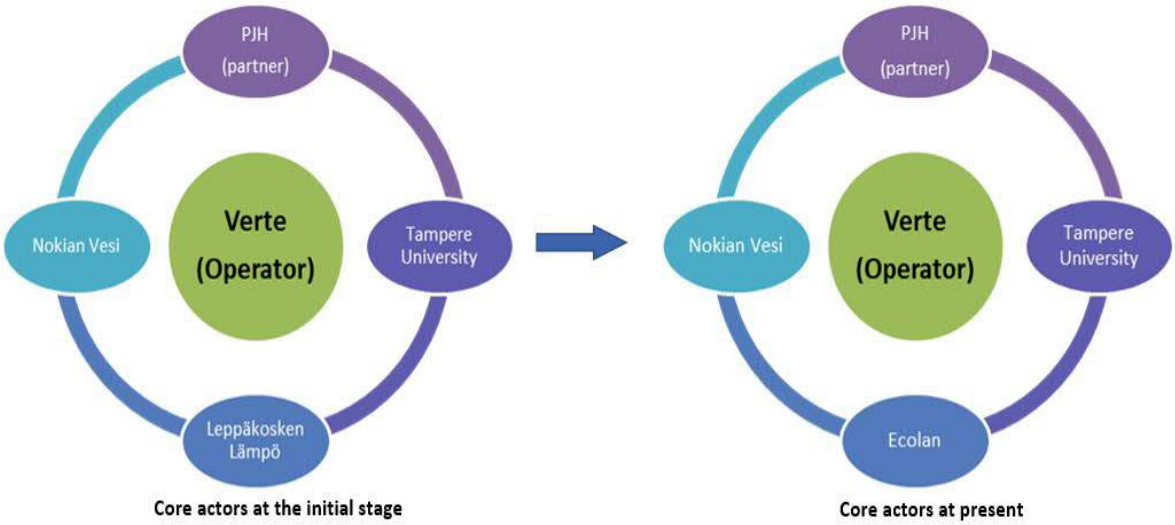

Figure 9. *Evolution in ECO3 core actor's structure.*

Besides, companies without having a direct role in different operating process plants are also involved in the ecosystem of the ECO3 area. For example, a Finnish company called Molok Oy manufacturing deep waste collection bins for waste management companies is also strongly involved in the ecosystem (ECO3, 2020a). Molok products are known globally and used daily by millions of people around the world due to the environment-friendly, cost-efficient, and time-saving system. The innovative deep collection bins developed by Molok are broadly used by Pirkanmaan Jätehuolto for its waste management services. Molok is operating in the city of Nokia and due to its proximity, the company was attracted to the ECO3 platform and decided to join the ecosystem (Jenni Rahkonen, Molok). Molok organized different events on its premises to support the collaboration process arrangement for the ECO3 system (ECO3, 2017b). The collaboration of Molok with ECO3 has a joint vision of development in the circular economy sector.

> *"Our expectation from ECO3 network is that it will give us the opportunity to grow in the international market, co-operation with regional companies, developing a relationship with the city of Nokia." says Jenni Rahkonen, Circular Economy Specialist of Molok.*

As waste is the enabler of IS in the ECO3 system, different environment-friendly waste collection bins provided by Molok is of great importance to initiate the circular bio-economy activities in the region. Besides, collaboration in the ECO3 area will provide Molok an opportunity to experiment with diverse pilot projects in the city of Nokia and develop better relationships with residents. For example, the company implemented the new project block collection bins for single houses, plastic collection points as part of the ECO3

operation process (Nokian Kaupunki, 2019a). Also, Molok has been actively involved in ECO3 with participation in several meetings and arranging demonstrations for ECO3 in their organization (ECO3, 2017b). Besides, the company has a strong research and development team which works in co-operation with Tampere University and Tekes and focuses on developing innovative products to meet the challenges posed by a variety of operating environments and cultures.

Along with the public and private sector organizations, the *local residents* are a significant part of the ECO3 system, as they are serving as the end consumers and waste producers at the same time. Currently, the city is working on bringing the residents into an active role in CE alongside the company actors from the public and private site, closing the "public-private-people" loop. The goal of ECO3 is to work on grass-root actions that would create awareness and lead to a more sustainable way of life for the residents (Kallio, Ermala and Seppänen, 2019). Yet, moving from a linear to circular economy model requires changing values for the whole society. To capture the market of bio-products consumers need to change their view and support green products. However, changing values are difficult as those are deeply integrated from birth. In such a scenario, the city of Nokia is encouraging residents and communicating the importance of bio-economy for a sustainable future (Nokian Kaupunki, 2018c).

To summarize the analysis of the primary and secondary data collected on the ECO3 ecosystem structure, it can be recognized that the main actors involved in the ecosystem are in collaboration at two different sectors: public organization actors and company actors. The actors interacting from these two different organizational sectors share a distant viewpoint and motive for joining the system. Public organization actors comprise municipalities, policymakers, research organizations, and business development platforms who are focused on developing the ECO3 as a system and consider it as a regional development platform. Public organization stakeholders consider the ECO3 platform as an enabler of bio and circular economy business innovations among companies operating in the locality while adding value for company actors through collaboration. The private company actors mainly include local business communities that consider the ECO3 system as a brand to get international recognition and fully driven by economic incentives for collaboration.

5.1.3 Factors impacting the organization of ECO3

The factors impacting the organization of ECO3 system either driving or inhibiting the development process have been categorized as “soft” and “hard” factors following the categorization approach mentioned by de Jesus (2018). The soft factors are related to the institutional, social, and environmental dimensions that indirectly influence the organization of ECO3 process development activities. While the hard factors related to different economical and technical facts that directly impacted the development of the ECO3 IS process or it can be said that the impact is physically visible or can be measured in monetary value. The driving and inhibiting factors represented in this section are derived from the interview session with the top management of the different organizations participating in the ECO3 system. The highlighted drivers and inhibitors represent the facts, elements, or activities that impacted the collaboration process development and overall progress of the ECO3 toward the creation of IS. The driving and inhibiting factors outlined from top management interviews were further categorized into soft and hard factors which are illustrated in Figure 10. The inhibiting factors are marked in a red box in figure 10 while the light green box represents the driving factors and the most important driving factors are presented in a darker green shade in the figure. Nevertheless, Finland’s waste legislation, location of the ECO3 business park, and Verte (platform company) have strongly driven the development of the ECO3 system toward an internationally competent circular economy hub. Hence, these three factors can be enlisted as the three key drivers to the evolution of the ECO3 IS system. The factors marked in figure 10 are discussed in detail to justify how these factors are driving or inhibiting the ECO3 IS process development.

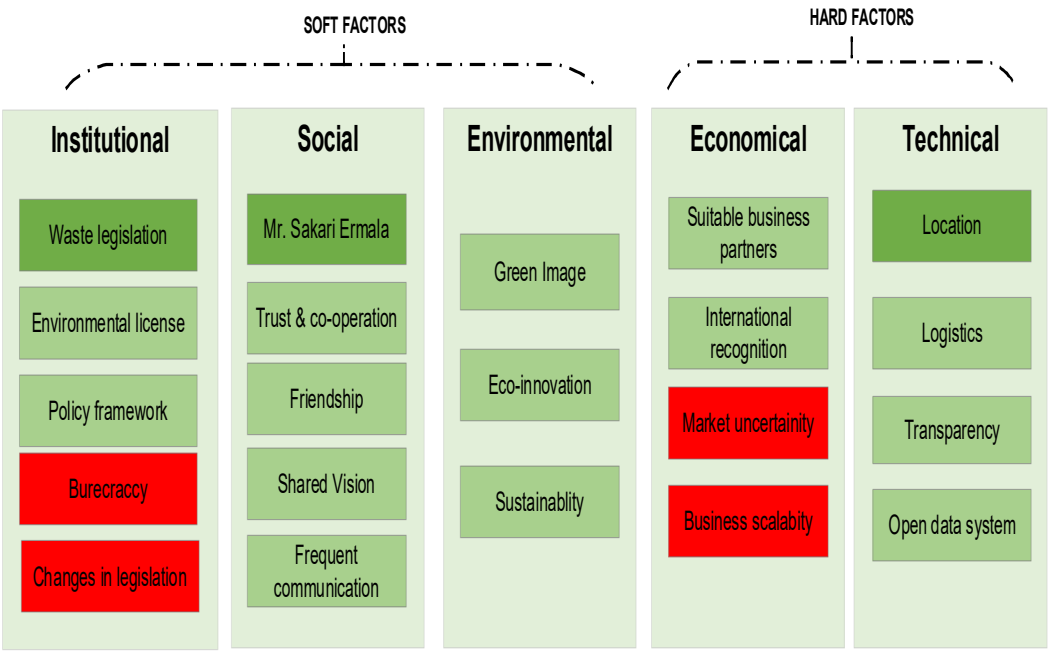

Figure 10. *Soft and hard factors impacting ECO3 system.*

Soft and hard factors as drivers

Institutional factors

The waste act of Finland, formulated by the government has been the main driver of several eco-industrial initiatives nationwide. The industrials need to strictly follow the waste management protocols implicated by the government. The waste flow data with the specification of different kinds of wastes, quality, and quantity are reported to the government actor at the regional level by companies. These waste flow data are the key enabler of initiating the IS process. Likewise, the Finnish national policy of transparency and open data systems motivated companies to share waste material flow information and evolve into a symbiotic relationship. Besides, the city development *"policy frame-work*" implemented by the Pirkanmaan liitto, exclusively supporting the circular economy as a strategy for regional development. Thus, regional level actors have been providing legislative support to advance CE businesses (Irina Simola, Ely-keskus).

Furthermore, the involvement of local and regional government actors in the ECO3 eco-system increased the reliability and value of the platform to a great extent. In Finland, companies need to attain an "*environmental license*" to start their operational process. This environmental license is authorized by ELY-keskus and the process of granting the license takes around 2 to 3 years after application. While the companies operating in the ECO3 area will attain this license on an instant basis, without any hassle. Such facilities offered by ELY-keskus, draw the attention of companies to co-operate and participate.

The core strategy of ECO3 is to collaborate companies toward IS which will follow CE principles. Therefore, local and regional actors are functioning as a driving agency to facilitate the integration of company actors in the ECO3 ecosystem.

Social factors

The main driver of the ECO3 system development is *Mr. Sakari Ermala* from Verte. Though the Nokia city municipality accredited the platform company Verte, the CEO of the company Mr. Sakari Ermala is *supremely determined from a personal level* to convert the present paper version of the ECO3 system into a practical level. Hence, Mr. Sakari Ermala can be termed as a *cata-person* driving the growth of the ECO3 system. Besides, the stronger network and relationships between industrial actors and Mr. Sakari Ermala was the key enabling factor of establishing primary connections. For the ECO3 platform development, Mr. Sakari Ermala beholds a *strong connection and friendship* with *Mr. Harri Kallio* from the Pirkanmaan Jätehuolto. At present their joined vision and partnership are the foremost driving forces to organize the collaboration process and connecting company actors to the platform.

Trust and co-operation are the most highlighted driving fact during the interviews for the emergence of a successful collaboration process. Tiina Laakkonen, Nokia city business director mentioned that the stakeholders involved are working cooperatively rather than competitively to jointly develop the ECO3 system, although the ecosystem might involve competitor organizations. Mr. Sakari Ermala mentioned that company actors need to develop a mindset of sharing information, ideas, and learning from each other for the progress of the ECO3 system. Till now ECO3 has grown recognition as a *co-operation center* for circular economy businesses which driven Tampereen Hyötypaalaus to collaborate in the platform (ECO3, 2018a). The company actors hold an open mindset to co-operate with different actors even with the competitors with a strong motivation to create new ideas. To that end, frequent *communication, interactions* among actors involved in the system is the most prominent way of growing psychological drivers like trust and co-operation. Besides, Verte organizes a monthly meeting with all the ecosystem actors and invites them to different events to participate, communicate, and meet others.

Environmental factors

To fight climate changes industrial actors all over the world are focusing on creating an environmentally sustainable operative process. The consumers also value green products. This gradual change in consumer behavior has driven many large corporations to integrate sustainability thinking into their operational process. For example, NCC one of the leading construction companies in the Nordic region has collaborated in the ECO3

platform as a response to the change in market demand. The company is developing green asphalt by collaborating with Ecolan for construction purposes (ECO3, 2020). Also, NCC posses environmental values and follows environmental permit measures in its operation. Hence, the green image will provide the companies with a competitive advantage to sustain in the market (Pirkko Eteläaho, Business Tampere).

Economical factors

The availability of important actors in the ecosystem can significantly increase the value of the platform for business to others. Just as the good partners identified in the ECO3 platform has significantly improved the business operation of Tramel and influenced them to join the network in the first place (ECO3, 2018b). Following that involvement of actors from a specific industrial sector can attract other organizations to join the network. Metsänhoitoyhdistys Pirkanmaa has been able to conduct its operation successfully in the ECO3 area due to the availability of the *right kind of partners* in the wood cycle. Parallel to that *presence of small and medium-sized* companies has also driven the fast growth of ECO3 system. This type of company has a low organizational structure where a decision for changes can be made flexibly and can collaborate with other organizations efficiently. For example, Revisol is open to exploring new partnerships in the ECO3 area and focuses on joint project development opportunities. The concept of CE to grow require co-operation in many forms, it can start from sharing infrastructure to physical resources to sharing a vision or values among actors (Pirkko Eteläaho, Business Tampere). ECO3 being a well-recognized project at the international level, small and medium-sized companies consider ECO3 as a gateway to step into the international market. Participation in a platform like ECO3 will enhance credibility and international recognition for the platform.

> *"Participation in ECO3 will help us to grow the international network and bring credibility for environmentally friendly operation." says Jenni Nurmi, Head of Infra Business of Ecolan.*

The circular economy is a recent trend in the business, the companies operating in this area mostly in the development phase and look for opportunities to grow in the international market. *ECO3 is considered as a brand* by SMEs to expand into the international market. For example, Tramel is planning to expand its recycling services to the extremely competitive Swedish market and develop a European sales force to grow into the international level through ECO3 collaboration (ECO3, 2018b). ECO3 is a platform to create new businesses around bio and circular economy centering the companies located in

the area. ECO3 is focused on selling the products and services generated locally at the national and international levels (Digipolis, 2020).

Technical factors

The *exclusive location* of the ECO3 business center has vigorously gained traction from the national level stakeholders and encouraged them to establish "ECO3" as a competent example of a CE business model around IS from Finland at the international level (Kallio, Ermala and Seppänen, 2019). Revisol Oy with offices located in Vaasa, Kaskinen, and, Ilmajoki considers ECO3 as an excellent opportunity to start its operation in an industrial region like Prikanmaa (ECO3, 2020b). Besides, the manufacturing plants of most of the companies in the Pirkanmaa region are located in the City of Nokia, where the ECO3 business area has been established. Therefore, companies with environmental concerns operating in the proximity easily got recognized with the ECO3 concept and became interested to join the platform. For instance, Stena one of the largest metal recycling companies from Sweden considers the Pirkanmaa region as a growth center in Finland. The company has been operating in the Nokia city since early 2007 and eagerly joined ECO3 to strengthen its business operation (ECO3, 2020b).

One of the main rationales behind Tramel joining the ECO3 is the park's location. Tramel's supply chain network involves a versatile set of actors from companies to households that require an efficient logistics system (ECO3, 2020a). The transportation linkage offered by ECO3 will ensure a uniform flow of materials and on-time delivery all over Finland. Jenni Nurmi from Ecolan Oy referred that handling of waste materials business is always a challenging task compared to other resources. The challenges initiate with the identification of suitable suppliers, risks in transportation due to hazardous content, and the operating process due to odor. However, in ECO3 the resources will be shared with the actors present in the specified area and will reduce the transportation cost. The recycled materials of Tampereen Hyötypaalaus are delivered directly to the paper industries located in the Helsinki and Pori area (ECO3, 2018a). Therefore, ECO3 location and business principle aligned with the requirements of the company to ensure the most efficient logistics of its operation. Thus, the cost-effective logistics structured by the ECO3 facility is a driver to grow connections for the platform.

The ECO3 system serves as a circular economy innovation center, financed research, and development organizations. Such *eco-innovation* practices initiated by research organizations firmly supported the development of ECO3. Circular economy and IS is a recent trend toward business, needs to be researched to innovate ways of utilizing materials. Alongside, ECO3 system offers the opportunity to experiment with pilot projects

which significantly driven small and medium-sized company actors to join ECO3 (ECO3, 2020c). ECO3 supports bio and circular economy innovations at the company and enables them to conduct industrial-scale operations at the platform. For example, Molok is getting the opportunity of implementing the pilot projects like block collection point, plastic collection point in the ECO3 area. Alongside, Wastewise is continually developing new products from the diverse recycled materials collected from the ECO3 system.

One of the main concerns while organizing a multi-actor ecosystem is maintaining t*ransparency*. The ECO3 system upholds transparency in the overall system as a value, that is appreciated by the company actors. For example, if the material flow data are visible to all the actors involved, it will create new possibilities, the actors might realize the potential and opportunity to collaborate with other organizations. Therefore, material flow data will be one of the main tools to connect the actors involved in the ecosystem.

> *"When you are doing something you are creating new possibilities for somebody else that is the idea of the ecosystem." says Harri Kallio, Managing Director of Pirkanmaan Jätehuolto.*

On the other hand, Finland is a quite good forerunner of maintaining transparency and implementing "open data system" in principle which functioning as a driving force to progress with the collaboration for ECO3. At this point, a digital platform with all the material flow data needs to be launched to attract companies in the ECO3 area. The digital platform can be developed in collaboration with the public and private sides through sharing ideas on what needs to be done, what information adds more value to the actors.

> *"The more there will be a different kind of stakeholder there will be a more holistic approach. There should be a combination of different kinds of actors like software developer, an engineer from process sites, marketing sites to initiate the process." says Irinia Simola, Bio and CE Expert of ELY-keskus.*

Hence, a well functioned digital database for material flows can be developed from the public site, especially, the ministry of environment, as they develop the waste legislation, and industries are bound to provide the waste information to them (Irina Simola, ELY-keskus).

Soft and hard factors as inhibitors

Institutional factors

One key concern while dealing with public sector organizations is the *bureaucracy* in organizational structure limiting the growth of overall development (Pirkko Eteläaho, Business Tampere). The bureaucracy results in extending the time of completion of the

project. Alongside frequent changes in Finnish legislation inhibits the companies to experiment with new projects for ECO3 development. For instance, Molok is planning to experiment with a plastic waste collection point for the ECO3 plastic recycling plant. However, the legislation on plastic waste recycling is yet to be implemented making the validity of Molok experiments in question.

> *"The bureaucracy present in public organizations slows the working process if we want to change something, inconsistent changes in the legislation, work as a limiting factor for any development activity." says Jenni Rahkonen, Circular Economy Specialist of Molok.*

Social factors

In the ECO3 area the public side, especially the city of Nokia has a negative attitude towards experimenting with bio-products. For example, the city of Nokia is not agreeing to utilize the construction materials manufactured in the ECO3 area for city infrastructure development. Additionally, the city of Nokia being a public sector actor is steered by public-laws, obligations which limits their capability of taking risks.

> *"In the beginning, people from the public sector, participate and appreciate the CE plans, but when it comes to the point of action they don't want to take risks, they are not acting as change-makers and do not encourage to use the end products in the area." says Jenni Nurmi, Head of Infra Business of Ecolan.*

Additionally, involving the residents, and agreeing with them to use the pilot projects is a major challenge itself as the local people have a different opinion for recycling operations, resistant to use something new.

Economical factors

Finland being a country of around 5.6 million people only, the *main challenge* of establishing the ECO3 area is ensuring *scalable business opportunities* (Sakari Ermala, Verte). Although collaborating actors from private companies possess a significant deal of challenges, yet once the business opportunity is visible they will be willing to operate in the area.

> *"Collaborating the companies is not difficult, if there is something attractive business opportunity they will surely join. If we have the actors, we can just go to a technology provider for digital solutions." says Sakari Ermala, CEO of Verte.*

At present, the main challenge faced by ECO3 is that the majority of the private company actors are resistant to share information. Thus, what needs to be done is still unclear as company sectors are not sharing ideas on how collaborations can be organized, or what

can be done for the advancement. The ownership model of business is still not clear. Another major issue is information sharing practices among the organizations already involved in the area. Every company or organization occupies its own organizational platform which is different from one another making it difficult to integrate.

Furthermore, assimilating suitable actors for the ECO3 ecosystem also poses significant challenges, as the platform is not only following the CE principles, rather it's moving toward developing a "Carbon neutral" economic system. Therefore, the participating organizations in the value chain should also follow a carbon-neutral economy approach in its own operational process. Again, most people are talking CE just as a hot topic in Europe, the industries are hardly concerned about circularity and environmental problems making it burdensome to identify suitable actors. The concept of bio and circular economy activities are still in the growing phase. Hence indicates the fact that the market for bioproducts is still uncertain. In some cases, the end consumers consider question the quality of bio-based products and consider those as waste (Mikko Nieminen, City of Nokia). Such approaches from consumers discourage companies to innovate bio-products.

At present, the actual need to develop the ECO3 system is to interact with different stakeholders to discuss how the common vision can be reached and what kind of benefits can be achieved through collaboration (Irina Simola, ELY-keskus). The enterprises already have consideration of CE in the business model and thinking of how to co-operate with others in the value chain by sharing the side streams. Therefore, the ECO3 system can be a great enabler of such work.

5.2 Case 2: Envitech system

The city of Forssa originated one of the utmost functioning circular economy business areas in Finland through IS by forming a collaboration with different organizations. Forssa is located in the southern part of Finland, surrounding three big cities: Helsinki, Tampere, and Turku with a population of around 17, 500 (Cavén, 2015). The exclusive location of the city has increased its attractiveness as a center for the economy and serving as a source of income/ employment opportunity for around 34,000 people (Mikkola, Randall and Hagberg, 2016). The city provides comprehensive high-quality services, education, housing for its residents in an environmentally friendly way. The Forssa sub-region is best recognized for its "Bright Green" approach of conducting business activities (Heinilä, 2019). The region focuses on conserving nature and promoting green values in every possible way. It can be in the form of encouraging residents toward an eco-friendly lifestyle at a personal level or can be applied at an organizational level to

save natural resources (Bright Green, 2019). The region is adopting the natural ecosystem approach for the management of energy sources and also supporting innovative business ideas that lean on green logistics, environmental sustainability (Bright GreenForssa, 2019).

The “Envitech” area of the Forssa sub-region is especially renowned for leading different bio-economy activities and operating diverse material recycling and waste processing plants (Kärkkäinen and Jokinen, 2019). The area has arranged one of the well-functioning IS with the participation of actors from the public and private sectors (Mikkola, Randall and Hagberg, 2016). The area offers intensive networking opportunities for organizations conducting sustainable business operations and can also impart its know-how to initiate circular economy business. At present, around 20 companies from recycling businesses are operating in the Envitech area with the creation of employment opportunities for approximately 200 people (Ayres, 2015). In addition to that city’s strategic goal of promoting bio-economy and reduced use of natural resources has enforced many organizations to adopt the circular economy as a business principle (Cavén, 2015). The bio and circular economy-based business area initiated in the Forssa sub-region is illustrated in Figure 11.

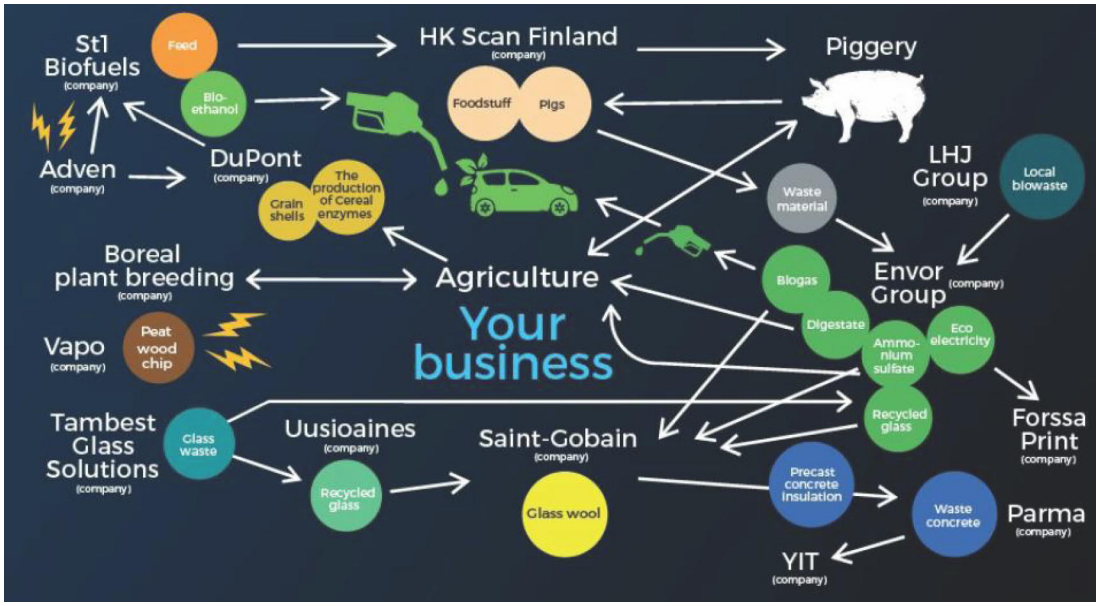

Figure 11. *Envitech operating concept* (Cavén, 2015).

As represented in the figure 11 agriculture and farmings are the core of the economic activities in the Forssa sub-region because of its prime location in the southern part of Finland (Kärkkäinen and Jokinen, 2019). Hence, the IS in the Forssa sub-region initiates

by keeping the agriculture sector at the center of the network. A part of the crops produced is sent to a local chemical company that extracts enzymes from crops. The effluents generated through this process are shared with a biofuel producing company located nearby. Ethanol is produced from the by-products and blended with traffic fuels for commercial use. Renewable energy sources are utilized for all the ethanol production processes and sourced from pellets and burning grain husks. The by-products generated through Ethanol production is dispatched to a local farming organization to produce pig foods. The pigs are then processed into food products and the bio-waste generated from the firm is distributed into two sectors. One part of the bio-waste is circulated back into the fields as fertilizer for farming purposes and the rest of the waste is further processed into energy.

The waste generated through different operating processes and bio-waste collected from domestic sources is further converted into biogas, organic fertilizer, and electricity through several phases. The digestion process of biogas production leaves behind digestate and ammonium sulfate to be used as fertilizer for crop production. The biogas produced is mainly used for the glass wool insulation manufacturing process as an energy source and a fraction of biogas is used as a fuel for vehicles. The glass wool insulation process also utilizes ammonium sulfate as a binding element recovered from biogas production. Recycled glass, cullets, and glass waste collected from the locality are also used for manufacturing glass wool insulation (Kärkkäinen and Jokinen, 2019). Glass wools are utilized to manufacture pre-cast concrete element and the waste materials generated through this process is recycled back. Alongside, an energy cycle exists in the IS network of Forssa region, where heat and electricity are produced from biomass like peat and wood chips. The above-mentioned information picture the operative process structure of the IS in Envitech area, while the next sections will respond to the research questions by first describing the IS evolution process of the Envitech area, secondly, illustrating the Envitech ecosystem with essential actor roles, and finally identifying the driving or inhibiting factors emerged along the process.

5.2.1 The IS process development of Envitech

Similar to the IS process development phase logic implemented in the ECO3 system, the evolution process of the Envitech system has been also categorized into three phases: emergence, probation, and development & expansion. Afterward, the organizational activities, development history, critical incidents, or events occurring at the different phases in Envitech evolution have been elaboratively discussed in this section.

Emergence phase:

In the year 1994 to 1995, the government of Finland enacted “new waste law” which enforced municipalities to join together (Ruohomaa, Salminen and Kunttu, 2019). The actors from municipalities started to establish new waste management companies, developed new landfill spaces, and create a new kind of environment for waste management activities. The Forssa city municipality also responded to the government’s movement of establishing waste management companies in the year 1995 (Immo Sundholm, LHJ group) Coincidently around the year 1988 to 1990, the municipal actors were already searching for a new landfill area as the old landfill area got filled. The municipal actors compared different locations in the region and fortunately, found the right place near the Forssa city center to be utilized as a new landfill area. At times, it was Finland’s very first landfill area to be established by following the EU’s regulations. Thus, the place and plan of waste management facilities were formulated a few years earlier before considering idea of the actual Envitech area (Immo Sundholm, LHJ group).

During that time the Forssa city municipal actors were also in search of a competent person to inaugurate the waste management activities in the newly identified landfill area (Antti Heinilä, city of Forssa). Though at the initial stage, decision-makers from the city of Forssa just considered constructing the new landfill area by following EU regulations, without the realization of future business potential (Antti Heinilä, city of Forssa). Mr. Immo Sundholm was chosen by the Forssa city municipality around the year 1995 to organize waste management activities in the chosen area. That year, the new waste management facility named *“Loimi-Hämeen Jätehuolto Oy (LHJ group)”* was established in the landfill area which can be referred to as the crucial step toward establishing the Envitech IS platform.

> *“The biggest idealizer of transforming the communal landfill area into an IS business platform was seen by Mr. Immo Sundholm.” says Antti Heinilä, Technical Director of the city of Forssa.*

After establishing waste management facilities, Mr. Immo Sundholm was looking for similar businesses to create an environmental ecosystem. Mr. Immo Sundholm driven by his personal interest wanted to secure the economic situation of the Forssa sub-region for the near future and started looking for new opportunities.

> *“I started to think about what can I do to help my home region in the future? If possible what new we can create to the Forssa’s region.” says Immo Sundholm, CEO of LHJ group.*

At that phase, the open spaces available in the new landfill area encouraged him to invite other companies to operate there. Gradually the area involved companies whose role was more than just a landfill operator. Mr. Immo Sundholm being a skilled and intelligent person visioned the probability of environmental businesses and started collaborating actors from the specified fields to progress the theoretical and practical infrastructure. Thus he individually initiated the concept of Envitech IS system.

> *"I realized that the environmental technology sector is developing so it can offer a different kind of possibilities for the future." says Immo Sundholm, CEO of LHJ group.*

Thus, the establishment of a waste management facility led to formulating the initial idea of creating an environmental-industrial park in the Forssa region around the year 1995 to 1996. The *fundamental idea* of *establishing the Envitech area mainly came from Mr. Immo Sundholm* from the LHJ group. Even the name "Envitech" was chosen by him when he paid a visit to an environmental technology exhibition in Germany named "Envitech" in Disedorphin. With a dream of initiating environmental technology businesses, Mr. Immo *Sundholm* considered Envitech as the most suitable name for the EIP to be organized in the Forssa region. *Nevertheless, it's worth mentioning that although the LHJ group is a publicly owned company, inaugurated by the City of Forssa, yet, the Envitech environmental business area was launched by Mr. Immo Sundholm individually.* The city of Forssa doesn't have any role in the initiation of the Envitech concept.

With preliminary planning and conceptualization by Mr. Immo Sundholm, the real start of the Envitech area happened during the year 1995 up to 1998. At the initial stage of infrastructure development, it was really necessary to manage fundings to take the concept into practical level. Fortunately, in the year 1995 when the Envitech area was being developed, it gained traction of several political leaders which led to managing easy finances for the project. The area received 25% of its investment from the EU level organizations (Immo Sundholm, LHJ group). Getting funded by organizations from the EU level was a crucial step toward the progression of the Envitech ecosystem. Besides national-level institutes like SITRA and TEKES also invested in the development of the Envitech area (Antti Heinilä, city of Forssa). At that time managing finances was not only important for infrastructure development but also for attracting companies to commence on the business network.

> *"When the area was being developed in the year 1995, it managed rather easy finances by a European organization." says Immo Sundholm, CEO of LHJ group.*

The IS process development phases of the Envitech system with the critical incidents are remarked in Figure 12.

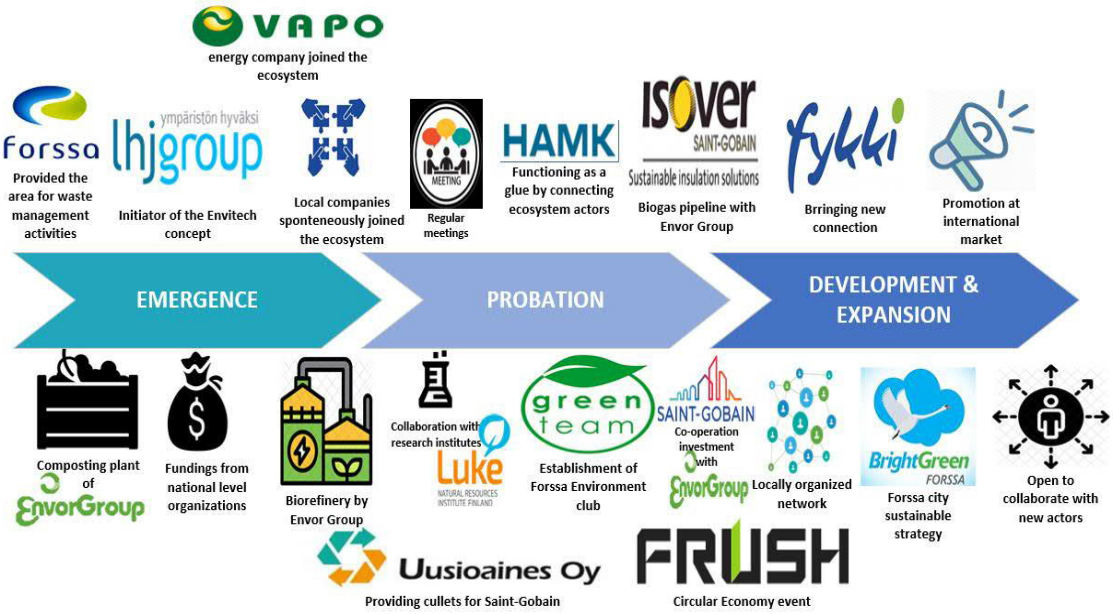

Figure 12. *Envitech IS development phases with critical incidents.*

Probation phase:

With the management of initial fundings from national and local level organizations, the probation phase of Envitech IS process development initiated where the main focus is to engage local company actors. The actual progress of an IS network occurs through the collaboration of local industrial actors. Forssa being a small city with 20,000 inhabitants only, all the industrial actors located in the area were familiar with each other making the process of collaboration easier (Ayres, 2015). Both economic and environmental business incentive was present among the ecosystem actors. Thus, the IS ecosystem initiated naturally among actors according to their own interests of environmental businesses, and the responsibilities were divided among actors based on what needed to be done (Immo Sundholm, LHJ group). However, throughout the process, Mr. Immo acted as the core actor of organizing collaborations,

> *"I know very well the environmental oriented companies in Finland and also from energy sector companies, so I personally have had a lot of negotiations during the years that we have an excellent area in Forssa, please come and build your company here though it was not my job rather a hobby." says Immo Sundholm, CEO of LHJ group.*

Eventually during the late 90s to early 2000 actors from different industrial sectors co-operatively approached to generate ideas for the new environmental technology businesses, executed several projects in collaboration with a different type of actors which resulted in stimulating the advancement of the Envitech system (Teräs *et al.*, 2014). In addition to that companies from private sectors started to collaborate under legislative pressure (waste law of Finland) to minimize the cost of waste management by forming an IS. When, the LHJ group also started operating in the Envitech area, at the same time *Envor Group*, a family-owned Finnish waste recycling company was searching for a place to initiate their new waste handling business in the Forssa sub-region and they find the Envitech area (Juha Strandberg, Envor Group). Everything comes down to the point that you need an allowance from the Government to handle different kinds of waste. Getting the environmental allowance to handle waste material operation at the individual level is a long procedure.

> *"The government allowed business with any kind of waste materials in the Envitech which is the main reason we started operating here." says Juha Strandberg, Managing Director of Envor Group.*

The municipalities supported the movement of local companies by providing the required facilities and infrastructure (Municipality of Kozani, 2020). The municipalities utilized a "land planning" tool to create a well organized industrial ecosystem in the Forssa sub-region to conduct circular economy activities (Antti Heinilä, city of Forssa). Nevertheless, organizing the collaboration among companies in the Forssa sub-region was comparatively easier,

> *"Compared to big cities like Tampere, it's a bit different in a small city like Forssa, it was easier to find partners in a small city like Forssa cause everybody knows each other. It was simple people were founding each other, talking with each other and divided work like you should do that I should do this and recognizing the way how they can work together" says Immo Sundholm, CEO of LHJ group.*

An important step toward building collaboration among companies and developing business relationships was the formation of the "*The Environment Club*" in the year 2006. The initiatives to establish the club were taken by regional development actors and local companies to encourage circular economy businesses and innovations (Kantola, Nazir and Barath, 2018). The club functioned actively and contributed to the development of the Forssa sub-regional environmental strategy. The next year in 2007, the club set the strategy of conducting environmental businesses, research, and education in the Forssa region. With active functionality during the year 2006 to 2010, the club activities were

replaced by *Forssa Region Development Center, FYKKI* (publicly owned company) (Teräs *et al.*, 2014).

Although the “closed-loop system” was initiated in the Envitech area at the beginning of the decade 2000, the progress of the platform was rather quite slow at that time. The number of circular economy innovations per year in the Envitech area escalated significantly during the period 2000 to 2010 (Teräs *et al.*, 2014). A revolutionary step toward the evolution of the Envitech area was an announcement from the Envor Group to invest in a bio-refinery in the Envitech system in the year 2014 (Juha Strandberg, Envor Group). The bio-refinery was planned to be established in an area of 100 ha that will produce bioethanol from around 340,000 tonnes of energy grains (Pirkkamaa, 2013). The bio-refinery opened the opportunity to integrate several circular economy businesses in the area. The bio-gas plant launched by Envor Group in the Envitech platform was Finland's largest bio-refinery during that time. The concept of bio-economy holds the potential of creating synergies among industrials and can operate at an optimum level with the collaboration of actors from different sites.

Thus, the collaboration process toward creating IS progressed naturally among actors according to their interests of environmental businesses and the responsibilities were divided among the ecosystem actors based on what needed to be done. Hence, it can be acknowledged that the IS in the Forssa sub-region evolved as a *self-organized symbiotic model* from the *local companies* with the support of municipalities as a regional development strategy. Eventually, the IS encouraged innovation practices among companies and resulted in the initiation of many new recycling businesses operations around the circular economy in the Forssa sub-region. To support innovation practices, research institutions like *Natural Resources Institute Finland (LUKE), Häme University of Applied Sciences (HAMK)* got involved in the Envitech ecosystem. Apart from that many new companies eagerly wanted to operate in a symbiotic network to have cost-effectiveness in operations.

Development and expansion phase:

The development and expansion phase illustrates how the IS system get promoted at the national and international level and its future potentiality. This phase can be a continuous development process if the scope of expanding the ecosystem remains open. In this phase, the existing relationships among actors grow stronger and collaboratively approach to promote the business ecosystem at the international level. The idea is that marketing the platform will help the industrial actors of the ecosystem to grow in the international market. The huge economic success gained through the Envitech system

encouraged municipal actors to take the concept at a broader level which they referred as “Envi grow park” (Ayres, 2015). Thus, the Envitech system forced municipal actors to formulate a new circular economy strategy for the city.

> *“The success in Envitech area, circular economy is considered as a big part of Forssa city development strategy. In theory, strategy results in actions while in Forssa actions have encouraged to develop a strategy.” says Antti Heinilä, Technical Director of the city of Forssa.*

To support the expansion, the Envitech concept was first launched in Brussels in the year 2007 (Teräs *et al.*, 2014). The Envitch system was also launched as a flagship project to support the local bio-economy businesses of the Forssa sub-region. Though the bio-economy in the Envitech area was already functioning properly for a long time, the term “bio-economy” was not common itself among industrials and local actors. Hence, the business idea of closed-loop cycling of materials and energy was developed during a study tour in the EU office at Brussels through a general brainstorming process to create an example of an internationally excellent bio-economy project (Teräs *et al.*, 2014).

It's worth mentioning that the strategy developed by the Forssa Environment club paved the way for co-operation among industrials to do circular businesses and resulted in the initiation of the “Bright Green Forssa” concept in the year 2008 (Teräs *et al.*, 2014). The “Bright Green Forssa” approach was launched by Forssa municipal actors to encourage environmental businesses for bringing out ecological products that will support the development of the Forssa as a sustainable city (Bright GreenForssa, 2019). Although in this case, the success achieved through the Envitech area encouraged the Forssa city actor to develop the Bright Green concept.

> *“Bright Green Forssa is the slogan of Forssa, while the city strategy is to encourage circular economy and sustainable development and the Envitech area is one concrete exapmle of such actions.” says Antti Heinilä, Technical Director of the city of Forssa.*

To boost up the motivation of companies to conduct ecological operations the municipal actors decided to provide the “Bright Green” certificate as an honor (Antti Heinilä, city of Forssa). Moreover, the Forssa regional development actors organized a visit to the world-famous Kalundborg IS in Denmark with vigorous participation of local companies (Teräs *et al.*, 2014). The objective of the visit was to recognize the underlying success factors of the Kalundborg IS which can be implemented in the advancement of the Envitech area.

Furthermore, in the year 2014, the national policy framework of the Finnish government focused on promoting the bio-economy as a business strategy (Winquist *et al.*, 2019). The policy focused on creating an environment that will support local business actors operating in the bio-economy area and performing innovations in that particular area. Following that the “Innovative City Programme” funded by the government and the EU included bio-economy as one of the themes to develop sustainable cities and focused on engaging actors in collaboration at cross-regional and international levels (Tekes, 2020). The national-level policy framework focused on enhancing Finland’s competitiveness to fight climate changes and conducting sustainable business operations. Hence, the *Finnish national policy program* can be considered as a tool that advanced the Envitech system (Teräs *et al.*, 2014).

Besides, the business development platform of Forssa, FYKKI is actively participating in different events like the world circular economy forum, regularly meeting with companies operating in the Envitech area to further growth of the area. The “FRUSH” event, especially focused on circular economy is organized for two days in Forssa where the companies get the possibility to meet with new partners. To support the network growth, FYKKI developed marketing material for Business Finland with a description of the Envitech area, so that Business Finland can advertise the area and bring in new partners (Timo Kärkkäinen, FYKKI). In the year 2019, the actor from FYKKI participated in a circular economy event organized by SITRA in Helsinki to introduce the Envitech symbiosis concept to the actors who were interested. International level actors were also present in that event. Nevertheless, the organization is in continuous contact with company actors to the advancement of the area.

> *“We are deciding together with the companies how to introduce the Envitech system to the world.” says Timo Kärkkäinen, Business Developer of FYKKI.*

The bio-economy strategy is firmly aligned with the main economic activities of Finland around agriculture, forestry, energy, and includes the opportunity of creating linkages among organizations by forming a stronger ecosystem to fight environmental challenges (Teräs *et al.*, 2014). Besides, the Forssa city actors are actively trying to promote the Envitech area at present, as it will bring more economy to the area. The 5 municipalities of the Forssa sub-region are paying half of the salary of Mr. Harri Mttila to the HAMK (Harri Mattila, HAMK). The agreement between these organizations and the university is developed in such a way that 50% workload of Mr. Harri will contribute to the development of Forssa “Bright Green Strategy”.

> *"Whenever I am traveling around in Finland or abroad, I am carrying the picture of IS of Forssa to get it more recognition and investments. All the time it's grabbing the attention of international actors and that's how we are contributing to the development of Forssa IS." says Harri Mattila, Adjunct Professor of HAMK.*

Such initiatives from local and national governments of acknowledging bio-economy strongly promoted the Envitech system as a model to the actors of different organizational levels. Thus, with firm support from the national, regional, and local level actors the Envitech system gradually evolved into its current phase and still embraces the opportunity of growing business networks for the Forssa sub-regional development.

5.2.2 Ecosystem of Envitech

The Envitech symbiosis platform is widely recognized as an environmental industrial ecosystem, one of the first eco-industrial initiatives in Finland (FYKKI, 2020). The ecosystem of the area evolved organically with three organizations playing the central role in the overall development phases. The *operational ecosystem* of the platform is mainly comprised of closely *located industrial actors* from waste management, energy and, glass recycling sectors. Active co-operation among the public-private organization is strongly visible in the ecosystem while intensive networking with local, national, and regional level stakeholders intensified the potentiality of the ecosystem (Mikkola, Randall and Hagberg, 2016). In addition to that regional institutions like universities, research centers, business development platforms collaborate with the aim of taking the Envitech area to the next level. Besides, numerous companies around the environmental technology and energy sector have been originated in the city of Forssa which eventually joined the Envitech ecosystem. The Envitech ecosystem is considered as a hub of "*environmental expertise*" to support and promote regional eco-efficient businesses (Ayres, 2015). However, Forssa being a small sub-region in Finland, the Envitech operating ecosystem comprised of a limited number of actors for operational activity, yet it is one of the most well-functioning symbiosis platforms in Finland (Cavén, 2015; Mikkola, Randall and Hagberg, 2016). The participating companies and organizations in the Envitech are have been illustrated in Figure 13.

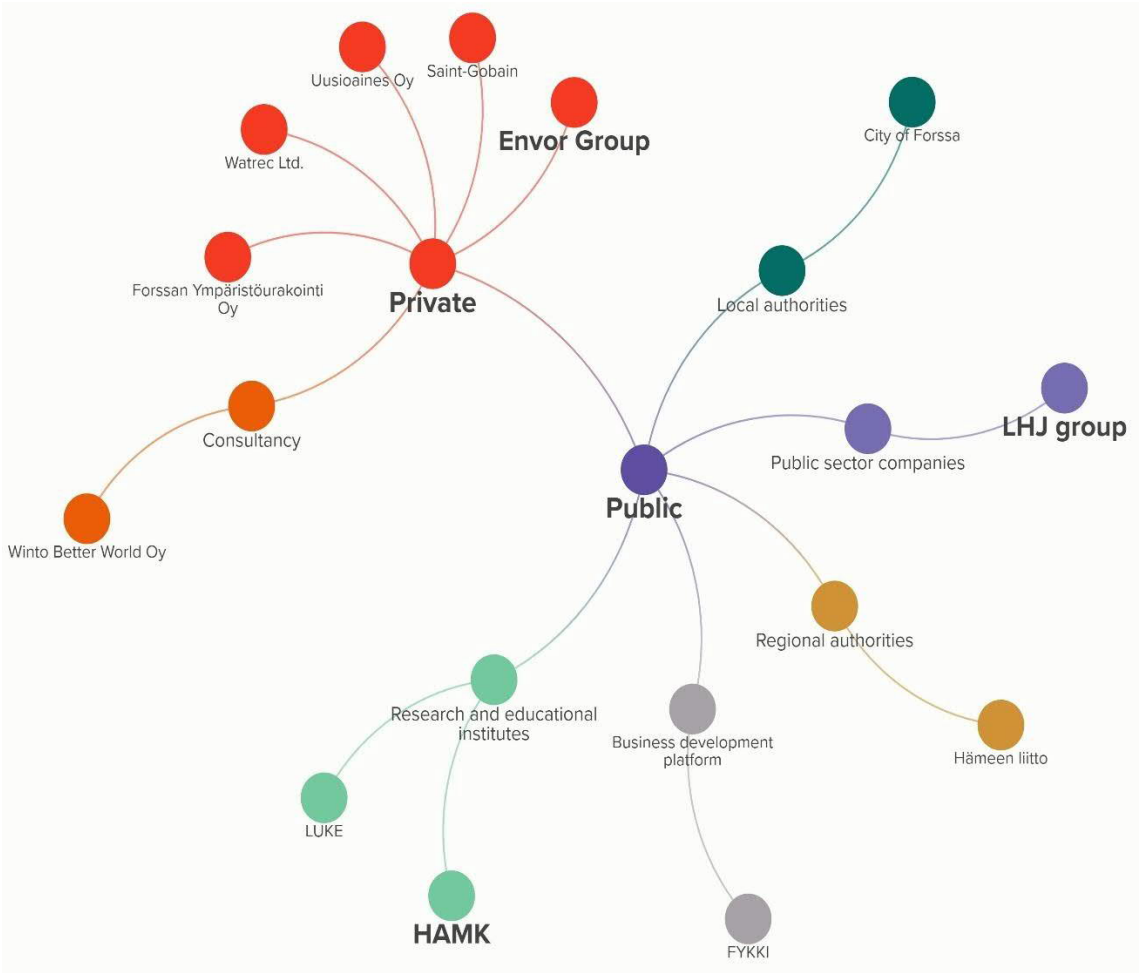

Figure 13. *Envitech ecosystem actors.*

As illustrated in figure 13 the Envitech ecosystem comprises actors from public and private sector organizations. The public sector organizations are mainly comprised of municipalities, business development platforms, educational, and research institutes. The private sector cluster is mainly comprised of companies operating in the Forssa. The core actors of the Envitech IS ecosystem has been bolded in figure 13. The later section will explicitly discuss the role, motivation, and expectations of different public and private sector actors involved in the ecosystem. The public organization actors and company actors are further summarized in Table 8. The organization type of public sector actors is highlighted with gray shade in table 8.

Table 8. *Public and company actors in Envitech.*

Public organization actors		
Local authorities	***Regional authorities***	***Business development platform***
City of Forssa	Hämeen liitto	FYKKI
Public sector company		***Research and educational institutes***
Loimi-Hämeen Jätehuolto Oy (LHJ group)		Natural Resources Institue Finland (LUKE)
		Häme University of Applied Sciences (HAMK)
Company actors		
Envor Group	Forssan Ympäristöurakointi Oy	***Consultancy***
Uusioaines Oy	Saint-Gobain	Winto Better World Oy
Watrec Ltd.		

Public organization actors in the Envitech ecosystem:

Public sector authorities from different levels (based on zone) mainly functioned as intermediaries in the evolution of the Envitech ecosystem. In Finland, there are three levels: local level (city of Forssa level), regional level (Kanta-Häme), and Finland national level, support from all these three different levels is really important to establish the IS system in the form of an EIP (Immo Sundholm, LHJ group). The presence of regional-level actors in an industrial ecosystem is significant as the organization's main focus is to support different regional development activities. The regional councils work in close co-operation with local companies and municipal actors which is proven to be beneficial to arrange collaboration among companies (Teräs et al., 2014). The regional council of Häme supported the growth of the Envitech ecosystem in every aspect (Ayres, 2015).

The key role of local-level actors from the Forssa municipality was confined to only initiating the concept of a municipal waste management company followed by the EU legislation (Kantola, Nazir and Barath, 2018). The municipal actors hired a competent person to organize waste management activities and made a zoning plan to find a suitable place where the Envitech ecosystem activities are organized at present (Antti Heinilä, city of Forssa).

> *"City of Forssa don't have any significant role since they hired me to organize the waste management activities in the Forssa region. It was more or less the natural idea to build up IS in Forssa." says Immo Sundholm, CEO of LHJ group.*

There was *insignificant from the city of Forssa* in the establishment of the Envitech ecosystem, rather the *idea of Envitech came from Mr. Immo Sundholm, an individual company actor*. Despite the fact that the Forssa city actors didn't have any major contribution in organizing the Envitech ecosystem yet they developed policies, assisted companies to manage environmental permits operating in the area (Mikkola, Randall and Hagberg, 2016). The city actors were responsible for ensuring that all the Envitech ecosystem actors would get similar opportunities and privileges. Over the years, the municipal actors initiated some negotiations with companies to collaborate in the Envitech ecosystem, unfortunately, the outcome was not successful.

Recently the city of Forssa sketched a "*town plan*" based on existing IS on the Envitech area (Antti Heinilä, city of Forssa). The town plan is structured in a way that will support and encourage companies to initiate circular economy activities in the Forssa region and create the opportunity of expanding existing operations. The concept of circular economy and sustainability thinking is becoming important in the whole world and driving toward integrating such an approach in business activities. The municipal actors perceive a higher expectation from the Envitech area and consider it as an opportunity to bring an economic boom in the Forssa sub-region.

> *"Forssa was left out during the economic boom that occurred in Finland by electronic companies like Nokia. The city of Forssa didn't get any share of the Nokia boom. Now we have the advantage of next coming big economic boom through sustainable businesses, we are trying everything to get our share." says Antti Heinilä, Technical Director of the city of Forssa.*

On the other hand inclusive of local and regional level actors, the role of national-level players was limited to implicating waste legislation nationwide. The national-level actors can take more robust actions to promote bio and circular economy activities. When the legislations become tighter companies are enforced to think about their waste streams which will support the growth of EIPs (Antti Heinilä, city of Forssa).

Research and educational institutes:

In Forssa, the research institutes have established a dynamic collaboration that is also significantly visible in the Envitech area (Cavén, 2015). The research institutes are working co-operatively to create new business opportunities in the area. The key education and research institutes involved in the advancement of the Envitech area are Häme University of Applied Sciences (HAMK) and Natural Resources Institute Finland (LUKE). HAMK is working in close connection with the companies involved in the IS, to get practical projects for their students straightway. For instance, HAMK conducted research in

co-operation under Horizon 2020 projects (e.g. WOOL2LOOP, an innovation project that focuses on the recovery of mineral wool waste from the construction industry) with Saint-Gobain, who are an important actor of the Envitech (Saint-Gobain, 2019a). Besides, the university formulated a research group in collaboration with LUKE with an aim of understanding IS and it's future. Their analysis will contribute to the future development of the IS in the future.

> *"Our role is to keep in connection and updated with these companies, cause we as an outsider it provides us less opportunity for business development or selecting companies to join the ecosystem." says Harri Mattila, Adjunct Professor of HAMK.*

LUKE is conducting different background research for example bio-fertilizer, grain production (LUKE, 2020). Thus, though they are not located in the area, yet they are part of the ecosystem. HAMK and LUKE overlook the whole Envitech ecosystem from an outsider perspective, conduct different projects which require co-operation among companies creating the opportunity for further symbiosis (Juha Strandberg, Envor group).

> *"We Envor Group are focused on our individual operation, same goes with the LHJ group whereas research organizations like HAMK act as a glue to combine us for further symbiosis. There is all the time somebody thinking the whole area where co-operation can be created." says Juha Strandberg, Managing Director of Envor Group.*

Therefore, co-operation with HAMK and LUKE is essential for the development of the Envitech area as the university also acts as a facilitator to create IS synergies. The research results are integrated into the industrial processes that resulted in gaining environmental and economic benefits.

Intermediaries from the public sector:

The business development platform of the Forssa, *FYKKI* became a part of the broader ecosystem of the Envitech area at the later phases. The main responsibility of the organization has been to create co-operation among companies operating in the Envitech area with other industrial from the city of Forssa. To initiate collaboration FYKKI organizes meetings in presence of the group of companies and with the city actor to identify what further can be done. Thus, the role of FYKKI has been to bring more companies into the Envitech area.

> *"What interest they do have? and How can we help those to achieve their goals?" says Timo Kärkkäinen, Business Developer of FYKKI.*

The company is not directly involved in any business in the Envitech area, rather they collect people to collaborate, initiate talking together to develop the platform, create ideation about the ways of co-operation (Timo Kärkkäinen, FYKKI). The organization is aiming to create economic wealth for the city of Forssa and continually trying to find ways to help the companies operating in the city to have more employees.

> *"Our target is that the Forssa city will have more taxes, more employees in the city, the companies should have more possibilities to grow and we try to identify barriers toward the economic growth of companies." says Timo Kärkkäinen, Business Developer of FYKKI.*

Although the company don't have any specific target for developing the area, yet, they are trying to help the growth of the area as much as possible. FYKKI is hoping to get *new investments* for further development of the area (Timo Kärkkäinen, FYKKI). Besides, FYKKI has partners like SITRA, ELY-keskus, Business Finland, Hämeen liitto who are also involved in bringing new projects for the Envitech area. Therefore, even though *FYKKI is not financing any companies* directly rather they assist the companies operating in the Forssa area *to manage funding* by creating co-operation with financing organizations of Finland like Tekes, ELY-keskus, Business Finland (Timo Kärkkäinen, FYKKI).

Company actors in the Envitech ecosystem:

The company actors form the central ecosystem structure of the Envitech area. The *central actor* of the Envitech ecosystem is *Mr. Immo Sundholm*, the present CEO of LHJ group (publicly owned company), as he individually initiated the concept of the Envitech system. When Mr. Immo Sundholm was chosen for establishing the LHJ group, Finland was facing an economic recession with a severe effect in the Forssa sub-region with companies going out and the economy getting down. During that time, *Forssa being the home region* of Mr. Immo Sundholm was *driven by his personal interest* to bring *financial stability in the region*. The main actor of LHJ group being an environmentally oriented person, one of the main intentions of developing the Envitech ecosystem was to conduct recycling operations at a high level without causing any environmental damages (Immo Sundholm, LHJ group). Besides, he visioned a great future business potential of environmental technologies in the international market. Mr. Immo Sundholm played a significant role as a *champion* to organize the collaboration process among industrials. As he was well aware of the environmental industrial actors operating in the Forssa sub-region, *acted as a co-ordinator* for connecting companies.

> *"We were very oriented to environmental technology business for the future, so the people interested in that particular area with similar mindsets collaborated effortlessly and talked to each other." says Immo Sundholm, CEO of LHJ group.*

The basic company of LHJ group is *owned by municipalities* and holds responsible for municipal solid waste management activities (Kaskinen, 2019). However, the sister concerns of LHJ group is conducting waste management activities in other area and competing with private waste management companies in the open marketplace (LHJ group, 2020). The LHJ group collects around 50,000 tonnes of wastes annually from 200 regional collection points within 16 municipalities which are processed further. The company established 9 waste management stations and the utilization rate was nearly 100% in the year 2018 (Kaskinen, 2019). Different wastes collected under LHJ group can be categorized into three sources: municipalities & households, industrial waste and, contaminated soil, and hazardous waste. All the waste materials collected under the LHJ group are treated through the different waste processing plants and a part of the end materials is landfilled. In the Envitech area, the LHJ group functions as the main source of raw materials like metals, plastics, glass, papers, bio-waste providers for many circular economy activities (Kärkkäinen and Jokinen, 2019). Hence, the main incentive of Mr. Immo Sundholm to initiate the Envitech area was to improve the economy of the Forssa for the long term.

> *"Forssa is my home region and it was going down when I started here because of the recession in industrial cities. I really willed to help the city of Forssa to have a better future, wanted to create some new possibilities to create jobs for people, also my parents were living nearby at that time." says Immo Sundholm, CEO of LHJ group.*

Mr. Immo Sundholm from the LHJ group was the *core actor* in organizing the collaboration of the Envitech ecosystem. The meetings were organized, held discussions on what needs to be done for the future with all the other actors involved in the process. Even though the current ecosystem of the Envitech system comprises a versatile set of actors from the public and private sectors, the structure has evolved over the years with changes in the importance of actors. Throughout the years, the lead role is played *Mr. Immo Sundholm* from *LHJ group* with a strong role by *Mr. Juha Strandberg* from *Envor Group* and *Mr. Raimo Hendersen* (died already) from the *Forssa energy power plant* in developing and managing the Envitech ecosystem. The core actors of the Envitech ecosystem is illustrated in Figure 14.

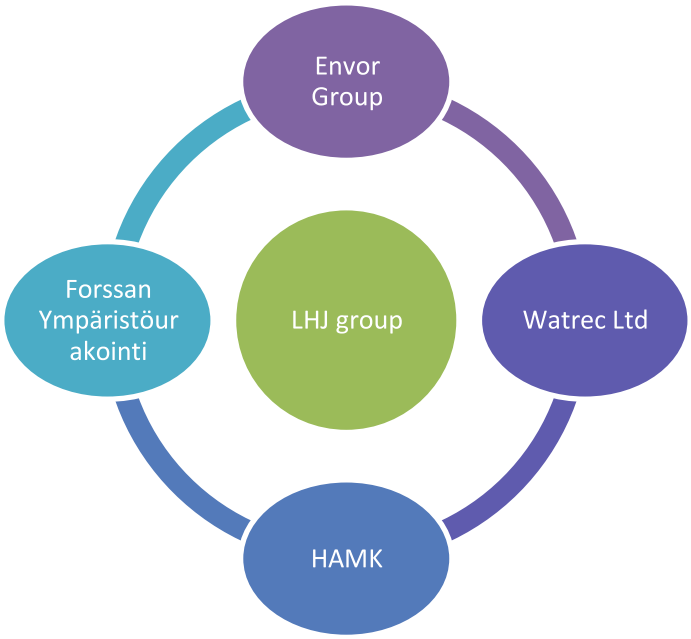

Figure 14. *Core actors of the Envitech ecosystem.*

After LHJ group, the companies to join the Envitech ecosystem were Envor Group and Forssa energy power plant with some other actors (Immo Sundholm, LHJ group). Consequently, Envor Group became the *second most important actor* in the Envitech ecosystem. Envor is a local family-based company, a forerunner of the circular economy in Finland (EnvorGroup, 2020). The circular economy activities in the Forssa sub-region are mainly organized and supervised by Envor Group, formerly known as *Fossan Romu* which initiated its journey in the *Forssa sub-region in 1964*. Over a brief period of time, Envor introduced many diverse recycling operations plants like paper, cardboard, and plastic management; waste management, fertilizer production from bio-waste. All of these different operating plants were brought under the same roof named as Envor group in 2006 (EnvorGroup, 2020).

Envor Group has a key role in bio and circular economy activity in the Forssa region and is considered as the heart of IS in the Forssa region (Cavén, 2015). Their know-how is specially required while developing a symbiosis platform like Envitech area. Envor Group started its symbiotic operations by establishing co-operation with HK scan group, one of the largest food manufacturing companies in Finland (Kärkkäinen and Jokinen, 2019). The slaughtered waste generated from HK Scan operation was dumped as a landfill while the Envor Group introduced a smart way of dealing with the waste (Juha Strandberg, Envor Group).

> *"We were thinking there could be a smarter way of dealing with the slaughter waste and then came up with the idea of composting in our premises." says Juha Strandberg, Managing Director of Envor Group.*

Afterward, the company started composting operation in the Envitech area, then established the biogas plant. In the Envitech area, Envor Group has been specially, responsible for the Biogas plant and formed a symbiotic relationship with many other actors. The company has been collecting bio-waste from regional waste management company LHJ group for their own operative processes for a long time and continued to do the same in the Envitech area. Envor Group also started a symbiotic relation with *Boreal Plant Breeding Ltd*. as a provider of bio-fertilizer for crop production. As Envor Group is conducting different recycling operations, the company already made many connections for its own business operations which also became a part of the Envitech ecosystem. For instance, Envor Group inaugurated symbiosis with *Saint-Gobain Isover* by supplying biogas for their production process. This provided the opportunity to Saint-Gobain to replace propane as fuel with biogas which is more environmentally friendly and cost-efficient (Saint-Gobain, 2019b).

> *"We have a direct biogas line from here (the Envitech area) to Saint-Gobain Isover plant and they use our biogas in their production." says Juha Strandberg, Managing Director of Envor Group.*

In terms of network expansion, Envor Group always strategized *looking for partners, not customers* to join the ecosystem (Juha Strandberg, Envor Group). For instance, the biogas produced by Envor Group is sold to Saint-Gobain as fuel, on the other hand, the biowaste generated during the production process of Saint-Gobain is again utilized by Envor Group creating a symbiotic relationship. Thus, Envor Group focuses on connecting companies as a partner for the closed-loop operation.

> *"Co-operation is two ways, it's not only just we are providing the services which resulted in growing the ecosystem network." says Juha Strandberg, Managing Director of Envor Group.*

Furthermore, a crucial symbiotic structure has been originated through Envitech system around glass recycling operation. Envor Group and *Uusioaines Oy* are mainly responsible for the glass recycling operating plant in the Envitech area (Kärkkäinen and Jokinen, 2019). *Tambest Glass Solutions* has been in network with Uusioaines Oy and Envor Group as a glass waste provider for these glass recycling operations in the platform. *Uusioaines Oy,* a Finnish glass recycling company based in the Forssa region is manufacturing diverse glass products (bottle, float, windshields) (Uusioaines Oy, 2020). Apart

from Tambest Glass Solutions, the company has been partnered with many other organizations to collect recyclable glass materials for their own production processes. The glass cullets formulated through glass recycling operations by Envor Group and Uusioaines are distributed to Saint-Gobain Rakennustuotteet (Kärkkäinen and Jokinen, 2019).

Saint-Gobain Rakennustuotteet, a local glass wool insulation manufacturing company operating in the Forssa sub-region since 1971 (Saint-Gobain, 2019b). The company strategy implies sustainable use of resources and use of recycled glass materials for its production processes. Alongside, the company focuses on reducing carbon emission by utilizing green energy source (Saint-Gobain, 2019b). Almost 50% of the energy used in the company is biogas and around 15 000 tons of recycled glass are used for operating processes. The company was able to completely eliminate the use of fossil fuel, with renewable sources in the year 2010 (Saint-Gobain, 2019a). The company participated in numerous research and development projects to increase the efficiency of recycling operations. Nevertheless, companies like Boreal or Saint-Gobain one part of the ecosystem, yet not located in the area and not linked in a symbiotic relationship through sharing resources (materials or knowledge).

> *"Companies like Boreal is not located in the Envitech area, and are not directly linked to the Envitech system. Yet they are a part of the larger ecosystem of Envitech, as the bio-fertilizer produced by Envor from composting is sold to them." says Juha Strandberg, Managing Director of Envor Group.*

Furthermore, waste to energy conversion process has resulted in developing another symbiotic structure in the Envitech system. *Watrec*, a Finnish company with expertized knowledge of biogas plant design has developed its own operating process in the Envitech area (Teräs *et al.*, 2014). Watrec started its journey as a consultancy company for biogas plant designing in the year 2003 and was responsible for designing numerous biogas plants in all over Finland (Watrec, 2019). Since 2006 Watrec is working in collaboration with Sitra to bring technological advancement in the Biogas plant development sector. In the Envitech area, the company has been in collaboration with the LHJ group to utilize the biowaste and sludge as raw materials for the biogas production plant (Teräs *et al.*, 2014). Moreover, the biogas produced in the Envitech area is sold as an energy source for industrial production, household electricity, and as fuel for cars. Biogas provides the opportunity of gaining profit from waste, reduced emissions of greenhouse gases, and cost-effectiveness.

To conclude, although the ecosystem of Envitech comprises of actors from both the public organization and private company, yet in this case, the company actors are mainly

dominant. The whole idea of the Envitech area was initiated by a local company actor, Mr. Immo Sundholm individually and further the network developed with the spontaneous involvement of local company actors. Hence, the public organization actors are mainly functioning as intermediaries to bring new companies in the Envitech area. The company actors are responsible for their individual operations, established symbiotic relationships for Envitech, and are the final decision-makers to bring any changes in the Envitech system.

5.2.3 Factors impacting the organization of Envitech system

The factors mentioned in this section primarily highlight the facts that either driven or inhibited the collaboration process development among industrial actors, alongside the infrastructural development of the Envitech system as a business center. The emphasized driving or inhibiting factors are mostly compiled by top management interviews from various industrial actors supported by secondary information sources. The identified driving and inhibiting factors are further categorized as “soft” and “hard” factors following the categorization approach mentioned by de Jesus (2018). The soft and hard factors impacting the IS process development in Envitech area have been outlined in Figure 15. The driving factors are marked with green box shading in the figure while the inhibiting factors are marked in the red boxes. The deeper green shading in figure 15 indicates the main driving factors of the Envitech system. Nevertheless, the driving and inhibiting factors of the Envitech system are further discussed in detail.

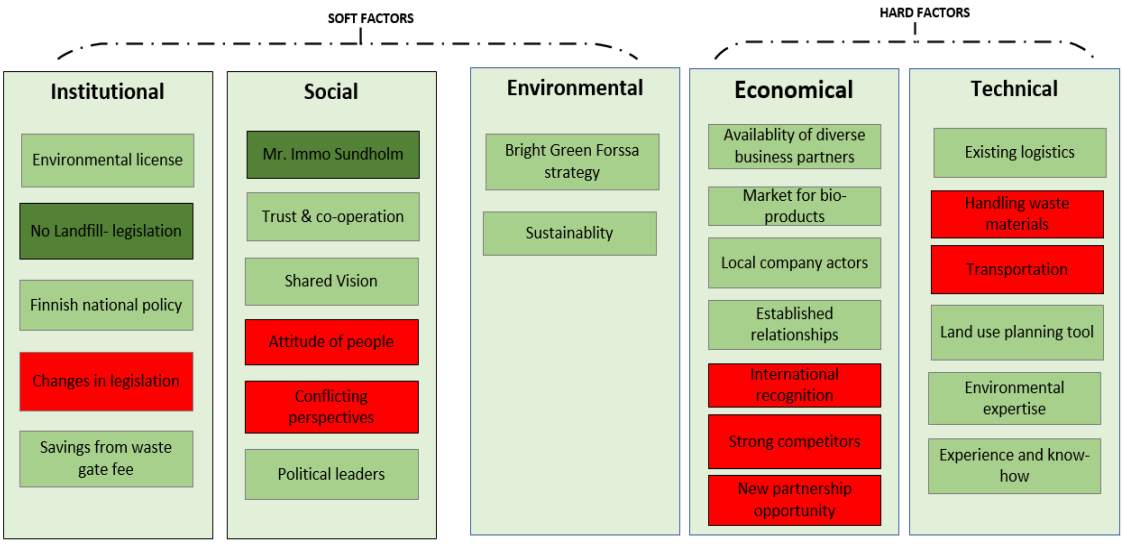

Figure 15. *Soft and hard factors impacting the Envitech system.*

Soft and hard factors as driver

Institutional factors

According to Mr. Immo Sundholm, the core driving force of initiating the Envitech area was the "*New waste legislation*" implemented by the government in Finland for waste management activities. The waste law enforced by the government encouraged many company actors to join the Envitech system. Besides the main driver behind Envor joining the Envitech area was the "*environmental license or permit*" provided by the government. Therefore, legislation plays a key role in driving companies to collaborate.

> *"First you need to have excellent legislation in force if you don't legislation in force then nothing happens in the waste management sector" says Immo Sundholm, CEO of LHJ group.*

Supporting the point of Mr. Immo Sundholm, Mr. Harri Mattila also considered legislation as the main driver of bringing companies together in the Envitch area. Today in Finland, almost nothing goes into landfill anymore, thus legislation is forcing companies to get benefits from all the waste of society which also implies bio-waste (Harri Mattila, HAMK). One important thing about legislation is that the landfill areas are charging "gate fees", for companies bringing the waste to the area. This gate fee has boosted the waste producers how they can manage the waste without bringing that to the landfill, thus savings from the gate fee has acted as the catalyst.

> *"Waste is a material which could not be treated everywhere, the geographical position of Forssa provides the opportunity of good transportation linkage by creating a circle capital region like Helsinki, Turku, Tampere, Hameenlinna, Pori, Lahti, and Forssa is located in the middle of this circle." says Juha Strandberg, Managing Director of Envor Group.*

Managing finances for a large scale project like Envitech is mentioned as one of the most crucial catalyzing factors by Mr. Immo Sundholm. Financing is always a major challenge to organize the IS system, for example how to finance new companies, how to manage investments for existing projects. That time *Finnish national policy* strategized to support and finance bio-economy projects like the Envitech system to fight climate changes, and encourage resource-efficient operations. To complement the Finnish national policy the EU level organizations decided to support bio-economy initiatives in Finland also. Alongside, the Envitech area gained *traction of political leaders* that contributed to the arrangement of easy finances for the advancement of the area.

Social factors

Co-operation among the ecosystem actors is a crucial fact to accelerate the collaboration process development of an IS system. An efficacious *co-operation among public and private sector actors* has been the *strength* of the Forssa sub-region for a long time (Ayres, 2015). The public-private co-operation has worked as a *competitive advantage* while organizing the bio-economy activities of the Envitech area. To foster co-operation among local and regional actors “Forssa Envitech Club” was established (Kantola, Nazir and Barath, 2018). The club assisted the development of relationships among company actors, along with company actors and public organizations. In addition to that Forssa energy and environment strategy set by the environment club paved the way for formulating regional clusters for bioeconomy activities. Thus, the *Forssa Environment Club* can be recognized as a powerful driver to elevate the collaboration process development for the Envitech area.

Besides, the companies involved in the area share a *mindset of co-operation* rather than competition to develop the platform. Developing a mindset of co-operation requires *frequent communication* among the actors involved in the ecosystem. The communication can be executed in a formal way like meetings or even can be initiated in an informal way. The purpose of frequent contacts is to develop a strong connection among the actors apart from just business relationships. Forssa being a small city all the industrial actors are located in proximity, which fostered the opportunity of frequent communication either in meetings or gatherings. Alongside this, most of the industrial actors are aware of the business activities of each other and can easily recognize the potential of collaborative operations. Therefore, the opportunity of *interactive communication* resulted in bringing huge success for the Envitech area.

The value and business potential of an IS system boost up with *the presence of important stakeholders*. The Forssa sub-region is well recognized for its *environmental expertise* all over Finland. A cluster of *technological leaders* is conducting cutting-edge researches in the region to develop *knowledge and competencies* on bioeconomy innovations. Alongside, research and educational institutes like HAMK, MTT, LUKE significantly contributed toward the advancement of the Envitech system by organizing bioeconomy seminars, prioritizing the agenda. However, the key driver behind achieving huge success on the Envitech ecosystem is the *personal interest or willingness* of the actors involved in the system to elevate the economy of Forssa. For example, the idea of the Envitech industrial platform was developed by Mr. Immo Sundholm due to his interest in improving the economy of Forssa. It's worth mentioning that the *strong leadership* approach by Mr. Immo Sundholm in organizing the activities and collaboration among actors resulted in

developing such a well-function and efficient symbiosis platform (Antti Heinilä, city of Forssa).

Environmental factors

"Bright Green Forssa" strategy developed by the regional council of Hämeen has encouraged local company actor's to integrate bio and CE thinking in their business operations. The regional development strategy, the regional innovation strategy for smart specialization, regional land use strategy all these policies were formulated by the local government to develop Forssa as a Green area (Interreg Europe, 2019). Besides, Forssa municipal actors in co-operation with Hämeen liitto, developed a sound policy framework to integrate *bio-economy and circular economy* as a regional development strategy (Teräs *et al.*, 2014). The policy framework enforced environmental companies to collaborate which resulted in progressing the Envitech ecosystem.

> *"The town plan allows utilization of ceratin kinds of waste by companies. For example, improving the soil, Forssa being a swamp area can be improved with glass or concrete waste." says Antti Heinilä, Technical Director of the city of Forssa.*

Economical factors

The biggest driver of Envitech area is that there are *many companies* operating in the area, opening the opportunity for more companies to initiate a symbiotic operation (Juha Strandberg, Envor Group). Besides, the company actors being the key decision-maker to bring any changes in the ecosystem fostered the development of the system

> *"Everything is based on the companies located there, they have been the main driving force to organize the ecosystem, everything starts from companies." says Timo Kärkkäinen, Business Developer of FYKKI.*

Besides, the companies involved in the ecosystem are operating in different *business areas, without being a competitor* to each other collaboratively focusing on the development of the Envitech area. For example, the power plant is generating heat and electricity for the city of Forssa, Envor Group is handling bio-waste treatment, recycling fraction of materials, cardboards collected from companies while the LHJ group is mainly responsible for municipal waste management activities and later other groups joined the ecosystem from different areas.

Nevertheless, showing the economic benefits of any co-operation has been the most successful to drive company actors. To foster the market for bio-products it has been legalized that bio-ethanol produced by ST1 should be used as one part of gasoline in the

Forssa area. The bio-products are comparatively cheaper. For example, the bio-fertilizers produced by Envor Group are cheaper compared to the ones available in the local market and it is used by the farming companies in the region.

> *"Money and legislations are the catalysts for organizing CE activities" says Harri Mattila, Adjunct Professor of HAMK.*

The Envitech area is considered a great opportunity for firms to grow at the international level. For instance, though the LHJ group started its operation in the Forssa area at present its sister group is co-operating and conducting researches in Germany, Luxembourg as a partner organization. The company already operated in Estonia and materials were brought to Fossa for treatment. Furthermore, the company is operating with ash treatment from incineration in multiple countries like Netherland, Sweden, and will operate in Lithuania. A similar approach in business network growth can be also found in Envor Group. The bio-waste refining plan initiated in the Envitech area will be replicated in India. *Growth seeking executives* in the companies has grown in the international market of China and Vietnam. Thus, although the business operation of the above-mentioned companies initiated at a local level in Finland, performing at the Envitech area assisted those companies to get international recognition, and eventually their business network grew into the Scandinavian level and finally many of them are now operating at the international level. Hence, the opportunity to grow in the international market has drawn the attention of several industrial actors to operate in the Envitech system.

Technical factors

The second most important driving factors of any business platform is its location. "Quite a clever land use planning by the city"- the city reserved a large space for waste management activities through the CE concept was not popular during that time (Harri Mattila, HAMK). Hence, the *supreme location* of an IS system ensures *cost-effective logistics* and most importantly the opportunity of expanding the business network. The *easy accessibility* of the capital area from Forssa city significantly increased its attractiveness as an economic hub for industrial operators. Therefore, inviting and attracting industrial actors to operate in the Envitech area of the Forssa sub-region was relatively less troublesome. Again, handling business with waste materials is comparatively challenging from other raw materials sources. For example, the waste materials decay, release odor, and might contain hazardous elements making the transportation process more complicated. Here, the location of the Envitech area surrounding big cities (as most of the industrial activities of Finland occurs in these regions) opened the opportunity for an efficient op-

erative process. Besides the city of Forssa beholds a long history of conducting businesses through IS since 1990. Although the terms like IS, bio-economy were not common during that time yet the experience gained through that process assisted the proceeding of the Envitech area. First place fulfilling the EU regulations, Envor Group biogas plant was the first of its kind in Finland, the circular economy map was existing for many years even before people were talking about the concept.

> *"Being the forerunner of quite many activities has drawn the interest of actors from outside Forssa." says Antti Heinilä, Technical Director of the city of Forssa.*

Soft and hard factors as inhibitor

Institutional factors

Frequent *changes in legislation* limit the progress of activities in the Envitech system (Immo Sundholm, LHJ group). For instance, LHJ group was looking for possibilities to treat contaminated soil in the Envitech area. Recently, the company signed a contract to bring and treat the contaminated soil from Helsinki in Forssa. The cost of waste management activities is already negotiated and signed in the contract while the project will be supposed to start 2 to 3 years later. If the legislation is changed during this time, it might increase the cost of waste management activities in the future. However, the contract has been signed with the current rate and it might result in hampering the economy of the LHJ group. Such changes in legislation will result in creating conflicts and incurring more money for waste management work.

> *"Handling of new kind of waste materials has been a challenge since the beginning in the Envitech area due to legislation." says Juha Strandberg, Managing Director of Envor Group.*

Besides frequent changes in political parties at the local and national levels also exerts a great deal of challenges to the advancement of the platform. The political actors change after every 4 years, and the situation (value and thinking) might be changed drastically which can inhibit the progress of any ongoing project (Immo Sundholm, LHJ group).

Legal actions regarding the reuse of different biomaterials, critical industrial wastes, plastics, food waste need to be strictly activated as these sources include a huge opportunity for recycling businesses. European Commission should formulate new policies to encourage recycled use of materials, promoting the secondary material markets, innovation

practices, eco-design practices and provide fundings for research in this area. For example, recycling plastic waste from different sources like packaging includes a huge opportunity for business. At present, reuse and recycle of plastic materials are done at a lower percentage in the European region which needs to be changed. Plastic materials cause environmental damages to a great extent while it can be reused or recycled by improving the durability of the materials. Therefore, it has been suggested that legislation should be developed in a way that will foster CE practices.

> *"We believe in future the regulations will be developed in a way that will drive companies to initiate circular economy business and create a market for circular economy products" says Timo Kärkkäinen, Business Developer of FYKKI.*

Social factors

A major challenge faced by industrial actors while dealing with bioeconomy is the common attitudes of consumers. Most often it's difficult to get the market value for bioeconomy products. Clients might have some anticipation with waste products, some clients prefer products made with raw material except waste producers (Antti Heinilä, city of Forssa). Even sometimes the customer organizations specifically restrict the usage of bio-materials in their product. For example, a company operating in the Forssa region specifically restricted the usage of bio-fertilizers in the field of their products as they consider it as waste. So bringing changes to the attitude of consumers is a great challenge.

> *"When you are dealing with circular economy its kind of everyday work to change the attitude of people and searching more opportunities." says Antti Heinilä, Technical Director of the city of Forssa.*

Economical factors

At present every company operating in the Envitech area are responsible for their own operational processes. However, at the initial development phases, the companies operating in the area gathered for a monthly meeting, what is coming and going, share ideas and thoughts for further development activities. It's high time the city of Forssa should take initiatives to manage the growth of the Envitech area, take a centralized approach to connect companies. Every actor involved in the ecosystem is solely focusing on their own operations only which inhibits the growth opportunity of the Envitech IS system.

> *"I am focusing to build up our group of companies (LHJ group), it's not my responsibility to develop the Envitech area as our organization LHJ group is my employer." says Immo Sundholm, CEO of LHJ group.*

There is always is competition among companies, finding common interest, and establishing co-operation are some of the main concerns to create such an ecosystem (*Timo Kärkkäinen*, FYKKI). At present, a substantial amount of waste materials generated in the Envitech area are further transported to distant places due to *lack of available partners* (Juha Strandberg, Envor Group). For example, plastic materials collected from various sources remain unutilized as there is no operator in the area.

> *"From my perspective, we don't need any central operator for the platform what we actually need is more partners who can further process the waste materials generated in the area." says Juha Strandberg, Managing Director of Envor Group.*

Apart from the identification of new partners, new customers, getting acknowledged by other companies, creating a more co-operative mindset among the existing companies and also co-operation from all over Finland and international level is required. Getting acknowledged by international actors is still needed.

> *"It is important for us to make the Envitech system more visible to the outer world for the development of the network." says Timo Kärkkäinen, Business Developer of FYKKI.*

Technical factors

The companies operating in the area are competitors in some contexts making difficulties in collaboration and joint operation. The whole plan of dealing with a large amount of waste requires so much ground space, while the Envitech area is established in a *limited area* (Antti Heinilä, city of Forssa). The companies operating in the area sometimes becomes competitive to reserve spaces for the processing of waste to prevent any kind of leakage so that they don't lose any possibilities. Besides, the Envitech ecosystem was the first of its kind in Finland, the initiation phase faced many difficulties like making anticipation for the future business potential, technical problems during operations like the release of odor.

> *"Being a forerunner also exerts plenty of challenges, as making anticipation is difficult. In the Envitech area, there were technical challenges like environmental problems (odor due to handling waste, sound pollution)." says Antti Heinilä, Technical Director of the city of Forssa.*

As the IS business area and bioeconomy were completely new in Finland during that time managing qualified staff for the activities also posed difficulties.

> *"It was difficult to find staffs who are eager to shift in the area. However, digitalization has solved these challenges to some extent, one can operate without being*

present while some activity requires physical appearance." says Immo Sundholm, CEO of LHJ group.

Furthermore, while dealing businesses with waste materials *distance* becomes a major challenge. If the distance becomes so long, the economy is lost in the process (Harri Mattila, HAMK). Although Envitech has been benefitted due to it's location in the middle of the growing market in Finland, near the Helsinki, Tampere, and Turku area. However, Forssa became a little bit far away as the business network is not growing anymore. The business network needs to be developed in connection with those developing economic zones.

"Biggest challenge is the location of the Envitech system, the cost of logistics is too high." says Juha Strandberg, Managing Director of Envor Group.

Nevertheless, Forssa sub-region has an abundant source of resources to support bioeconomy activities, along with technical expertise. Innovativeness, the number of eco-innovative practices in Forssa has increased enormously which fostered the growth of the Envitech platform for businesses. Digitalization offers a huge potential for creating new partnerships in the Envitech area. This will open the opportunity to collaborate with actors virtually from the international level and widen the value of the network.

6. COMPARISON BETWEEN ECO3 AND ENVITECH

This part of the research performs a comparative analysis between the above mentioned industrial symbiosis (IS) cases. Both of the IS systems have been organized in the form of an eco-industrial park (EIP) and based in Finland. The comparative analysis between cases will be performed following the three key research theme perspectives: the IS process development perspective, the IS ecosystem actors and their role perspectives, and the driving and inhibiting factors perspectives. Prior analysis some dimensions are defined under each researched theme perspective, based on which the IS cases will be compared. Furthermore, the case comparison will provide insights on the differences or similarities in Finnish IS setups and the learnings from these two Finnish IS cases can be implicated into other symbiosis initiatives. Nevertheless, the rationale behind analyzing the differences and similarities of these cases is to recognize the numerous successive and challenging elements from both cases that emerged throughout the collaboration process development of two different symbiosis cases in distant setups. The distinctive or similar features (those impacted positively) of each IS cases, can further provide guidelines to organize a new well-functioning IS set-up. At the same time, the successive elements from one case that are missing in another can be considered as a viable solution for future progress.

Even though the ECO3, as well as the Envitech system, are based in Finland, yet the analysis presented in Chapter 5 highlights the fact that both of the cases are rather distinctive. The unique features of both cases are strongly visible from the emergence pattern of the IS until the development and expansion phases of collaborating various actors. Furthermore, the ecosystem analysis of the ECO3 and Envitech system also points out the fact though it comprises a similar set of actors (in terms of public and private sector), yet their role and how they visualize the value and opportunity from these systems has been quite dissimilar. Lastly, in the context of soft and hard factors impacting the organization of activities either driving or inhibiting, the studied cases represent more of a similar set of factors. Thus, in reliance on the research data presented in chapter 5 the case "*ECO3*" can be categorized as a "*publicly driven IS*" whereas the "*Envitech*" case can be acknowledged as a "*company driven IS* " model. The rationale and justification behind this case categorization are further reviewed following the three key research question perspectives in this chapter.

6.1 The IS process development perspective

The very first emergence phase of the ECO3 system displays that it is a publicly organized IS model. In terms of *initiator,* the *city of Nokia* inaugurated the ECO3 park as part of the Kolmenkulma eco-industrial zone and followed a national and regional policy-driven approach to organize the system. Besides, ECO3 was specifically planned in the Pirkanmaa region to follow the national and regional policies of sustainable city development to be implicated at the local level. On the other hand, while contemplating the emergence story of the Evitech area it is rather clear and mentioned by many actors that the system's *biggest visionary* was *Mr. Immo Sundholm* (individual firm level actor) from the LHJ group. The city of Forssa allocated an area to organize new waste management activities and they did not have any plan for the future business possibility. Mr. Immo Sundholm was hired by Forssa municipal actors just to organize the new waste management facility, which is recognized as the LHJ group at present. With the establishment of LHJ group, Mr. Immo Sundholm was *driven by his personal interest* and launched the idea of a new environmental business in the remaining land (after the establishment of LHJ group) through the creation of symbiotic linkage among companies. This environmental business area was later named "Envitech" which was also chosen by Mr. Immo Sundholm during his visit to an environmental technology fair. Thus, Mr. Immo Sundholm was the main initiator of the Envitech concept. Thus, looking from the initiator dimension it is completely justifiable to categorize Envitech as "company driven IS**"** and ECO3 as a "publicly driven IS" model.

Besides, the rationale behind initiating the ECO3 system in the Pirkanmaa region also indicates a "public driven approach**"**. For instance, Tampere is the second-largest industrial city in Finland with numerous companies operating in the Nokia city, creating the opportunity to engage more actors. Alongside, the city's history and experiences of industrial activities aided the progress of the ECO3 system. Apart from that, Tampere city actor's set the strategy to develop it as a clean-tech hub and solutions, and initiatives like ECO3 is a remark toward that movement. In respect to *motivation*, the main motivation of the Nokia city actors (public) behind planning the park was *regional development through bio-economy* activities, bringing sustainability in business operations. On the other hand, the concept of Envitech area was drafted by an individual-firm level actor and the motivation was to *improve the economic situation of his home region*. In those days the Forssa region was facing an economic downturn with many companies leaving the area. In that critical situation, Mr. Immo Sundholm was incentivized by his own interest in executing something new in the area that will hold the economy for the long term

with the creation of employment opportunities as his parents were also living in that locality. Therefore, it can be argued that the organization of the Envitech system was rather a need for regional economic improvement nurtured by a company actor. Thus it can be said that the purpose of improving the local economy by Mr. Immo Sundholm later evolved into an EIP initiative.

The *core relationships* in the ECO3 area was mostly developed among the public sector organizations, the city of Nokia assigned a “Project manager” to centrally organize the activities. ECO3 area is formed by following a motto of “public-private-people-partnership.” The core relationships formed among Verte, PJH, Nokian Vesi, and Tampere University. While the Envitech area resulted from private company initiatives and local public organization's involvement was quite invisible. Along with the LHJ group, Envor Group (private company), Forssan Ympäristöurakointi Oy operated as one of the key anchor companies from the beginning in the Envitech area. In the city of Forssa IS started around 20 years ago, there was no presence of a project manager from the local government,

> *“I really hope that the city of Forssa should hire people who will look and discuss with company actors involved in the Envitech area, marketing the area at national and international level. The city of Forssa needs to be more active and can play a big role for further advancement of the area.” says Immo Sundholm, CEO of LHJ group.*

Thereby summing the activities that occurred during the emergence phase it is completely justified to categorize ECO3 as a “publicly driven IS model” and Envitech as a “company-driven IS model”.

The crucial part of any IS platform is organizing collaboration among company actors which can be recognized as the probation phase of an IS system. In both cases, primarily the co-located companies in the area joined the platform, defined the opportunity of creating further relationships. In respect to *network organization patterns*, in ECO3 the collaboration among companies was mainly *planned by Verte* (public organization) and offering platform-based services to organize collaboration among company actors. While in Envitech collaboration formed within the local company actors *autonomously*. It was further mentioned during interviews that organizing collaborations and co-operation among individual companies was comparatively easier in the Envitech system. Due to the small geographic area, the company actors were already known to each other and independently approached to join the ecosystem. Even some actors were operating in co-operation with each other for a long time even when the Envitech concept was not

established. Along with that the key initiator of the platform Mr. Immo Sundholm was already aware of the environmental companies operating in the area and had a connection with them. Therefore, the collaboration was organized in more of an informal way with the involvement of many company actors.

On the contrary, convincing private company actors to collaborate in the ECO3 system is one of the key challenges faced by the organizers at present. For instance, several companies operating in Nokia city joined the platform at the initial stage, yet many of them are just a part of the ecosystem without any active participation in the system development. Several actors who consider “ECO3 as a brand” and participation in the platform will develop the image for their own organization. Some actors specifically SMEs consider ECO3 an opportunity to get recognition from international companies and valuation for their bio and circular economy activities. Thereby, it can be acknowledged that the companies operating in the Forssa joined the Envitech system based on their own needs and actively performed to organize their business in the Envitech system while a majority of the company actors involved in the ECO3 system considering it as an opportunity to grow their individual business network without showing any collaborative approach toward ECO3 system development.

The development and expansion strategy followed in the systems is completely distant to each other. The core organizers strategized to promote the “ECO3 concept” to diverse national and international level actors to achieve recognition. The platform company Verte in collaboration with the anchor company PJH participated in multiple competitions and won prestigious awards like Eurocity. Such actions from key anchor organizations promoted the “ECO3 concept” at the global level as a “bio and circular economy business model”. Additionally, it opens the opportunity for the ECO3 ecosystem actors to operate in the international market. Besides extensive marketing and promotion yielded massive recognition for the ECO3 concept, drawing the attention of numerous important stakeholders that further aided the overall development of the system. The public sector organizations are focused on serving ECO3 as a “pilot and demonstration center” for circular economy activities in Finland. In contrast to the ECO3 approach, the Envitech is one of the less recognized yet well functioning IS systems of Finland. The explanation behind this could be that the symbiosis was organized by local company actors who mainly focused on improving their own business through symbiosis rather than considering the advancement of the system as a whole. For many years the Envitech ecosystem remains confined to the locality, without much consideration of the opportunity and approaches toward promoting the platform at the international level. Thus, the strategy

toward expanding the platform was mostly implicated by public sector actors in ECO3 while Envitech system development remains limited to local company actors.

6.2 Ecosystem perspective

The ecosystem analysis of ECO3 and Envitech area demonstrates that both the systems conglomerated a set of actors from the public and private organizations. Regardless, the role of this different organizational sector has been quite diverse in terms of incentives, expectations, and activities in ECO3 and Envitech. The evolution of the ECO3 ecosystem followed a top-down approach with municipal and regional actors playing the lead role from the beginning. The Nokia city municipal actors planned the ECO3 area to initiate business activities through IS as part of the regional development project. The primary collaborations were formed between Nokian Vesi (public) and PJH (regional waste management organization) to initiate the operational activities. Apart from this other public sector organizations like Tampere University joined the ecosystem and functioning as key anchor companies to develop the system. Moreover, all the activities from the operating process to organizing collaborations were planned by Verte in collaboration with PJH and Tampere University. Hereby, it is rather clear that the ECO3 ecosystem evolved as a *planned symbiosis model* driven by public sector actors.

Opposite of this, the ecosystem evolution pattern of the Envitech area followed a bottom-up approach where the role of company actors was significant throughout the journey. The key anchor companies of the Envitech area during the evolution phase were LHJ group and Envor Group. However, the incentive behind these anchor companies to participate in the area is rather different. For example, Envor Group started operating in the area due to the opportunity of handling business with a different kind of waste materials. Otherwise, it is a difficult and time-consuming process to manage the environmental license from the government to operate in any new area. Whereas Mr. Immo Sundholm (CEO of LHJ group) was hired by municipal actors to organize the waste management facilities, named as LHJ group only in a planned area. Later, Mr. Immo Sundholm from LHJ group individually initiated the concept of Envitech system. Nevertheless, to support the growth and success of the Envitech area, the local government opened the Forssa Environment club in the later phases to increase interaction among company actors. The environmental companies operating in the region spontaneously joined the Envitech ecosystem to receive benefits from symbiotic operations. Over the years the Envitech area emerged as a *self-organized IS model* mainly driven by *local company actors* in the Forssa area.

One of the interesting points is that though both of the IS systems have been organized with a primary objective of receiving economic benefits yet the perspective of the key organizers has been different. In the ECO3 ecosystem, the central operator is Mr. Sakari Ermala from Verte, highly motivated to convert the paper version of the structure into reality. Hence, the main incentive of Verte is to promote the ECO3 concept at the international market, operate as a project manager if other countries want to initiate their own ECO3 like operations, or can simply sell the concept to the project managers. At present, Verte is targeting to collaborate with bigger industrial cities like Turku, Helsinki to develop the business value of ECO3. Verte is providing a platform-based service to organize collaboration among company actors. Whereas there is no central actor to organize the activities in the Envitech ecosystem. Even though Mr. Immo Sundholm initiated the concept of environmental business in the Envitech area, still it was not his main responsibility. Mr. Immo Sundholm being a competent and expert person realized the *economic* potential of environmental technology business in the near future and made an attempt to collaborate with local companies to operate in the unused spaces of the new landfill site. Besides, the companies operating in the Forssa were already operating in co-operation with each other for a long time even when the term “symbiosis” was not introduced that considerably assisted the development of the Envitech system. Eventually, the environmental companies operating in the Forssa area became a part of the ecosystem by establishing business relationships with their existing and new partners. In this way, it is also evident that company-level actors were most prominent in the Envitech ecosystem while collaboration in ECO3 is mainly organized through Verte (public).

Furthermore, the analysis of case ecosystems illustrates the involvement of public organizations from different sectors such as fund providers, business development platforms, environmental, research institutes, educational organizations in both of the systems. Nevertheless, the role and frequency of participation of these organizational sectors at the IS system development showed a comparatively distant approach in ECO3 and Envitech. Since the beginning local, regional and, national-level organizations are playing a significant role in ECO3 either as the main platform company or as an *intermediary* to incentivize private sector companies to co-operate. Finnish national innovation center, SITRA remarked ECO3 as “Finnish roadmap toward CE”. Hence, the wider ECO3 ecosystem is a hub of business development platforms like Business Tampere, Business Nokia, Business Finland; institutions like SITRA, ELY-keskus, Pirkanmaan liitto who joined as a co-operation partner for the development of the nationally significant ECO3 area. On the other hand, initiatives like Envitech was first of its kind in Finland, the public sectors were not even aware of such systems at that time. The key role played by

Forssa municipal actors in the development of the Envitech ecosystem was to provide a land planning tool and the project received funding from the EU level organizations. However, the master plan of the area and activities was developed by company actors. In the later phases, the business development platform of Forssa, FYKKI became a part of the Envitech ecosystem to collaborate companies from national and international levels. Yet, Mr. Timo Kärkkäinen from FYKKI mentioned they are not operating for the Envitech area, neither receiving any financial incentives, rather facilitating the network growth, and referred to the local companies as the main actor of the system.

A key essential part of the IS ecosystem is fostering *eco-innovation practices* through the collaboration of research organizations and companies. The ECO3 system spawned a stronger *innovation ecosystem* with actors from research institutes like VTT, Tampere University. Besides the regional level actors developed the system with an aim of stimulating innovation practices around bio and circular economy, providing opportunities for SME company actors to run pilot projects in the area. On the other hand, the company actors involved in the Envitech ecosystem conduct innovation practices at the *individual firm level*, the success achieved through this process adds value to the Envitech system. However, the company actors run innovation practices to develop their own activities without consideration of the Envitech system development. Here, HAMK and LUKE playing a significant role by conducting different projects and innovations around bioeconomy in collaboration with the company actors for overall Envitech system development. These organizations are also conducting researches for their own benefits or as a responsibility. For example, the students of HAMK get the opportunity to conduct many projects in the Envitech area which enriched them with practical knowledge. On top of that these research organizations specifically HAMK function as a glue to connect the ecosystem actors for further symbiosis. They view the system as a whole from an outsider perspective and examine the way how new collaboration opportunities can be created.

Company actors are the core of the *operational ecosystem* in any IS process development. The operating system of the ECO3 rotates around four different cycles (nutrient, wood, technical, energy) probing a wide opportunity of collaboration with numerous actors. On the other hand, the Envitech ecosystem being organized by local level companies confined to a limited set of actors in the field of material recycling, energy, and different bio-based products. ECO3 is planned in a way that companies part of the operational ecosystem will construct their operating plants and share resources (material and human) in the same specified area. Whereas in Forssa different environmental companies were already operating in co-operation for a long time who later joined the Envitech ecosystem. Though the companies became a part of the Envitech ecosystem, they did

not shift their operating process in the same specified area. The reason behind this is that they were already operating quite nearby. Even some significant company actors of the broader ecosystem (e.g. Saint-Gobain) not necessarily engaged in symbiotic exchanges rather those are engaged as a customer of the platform.

Furthermore, the ECO3 system involves companies who as a part of the ecosystem remain responsible for the different organizational activities and run diverse projects through the ECO3 system without any efficient part in the operational activities. Besides, throughout the research, it was also identified in ECO3 there are some company actors without participation in any activities, rather just hanging around. These kinds of actors are operating in the locality remain a part of the system to keep updated with what is happening nearby and to exploit future value creation opportunities**.** While active participation is visible from small and medium-sized companies, as they don't have sufficient budget to experiment, and business growth for bioeconomy and perceive platforms like ECO3 as a great opportunity for them. They mostly consider ECO3 as a brand to enhance their organizational value and consider it will increase their reputation at the international level for conducting CE practices. While the Envitech ecosystem includes many big company actors who are more focused on their individual operations and sharing resources for their own needs. The wider ecosystem of Envitech also involves actors who rather just purchase services from the companies operating in the area. For example, Saint-Gobain purchases biogas from Envor Group and cullets from Uusioaines Oy for their glass recycling process plants. Thus, even though in Envitech the company actors are more focused on their individual operation, yet they are sharing resources by forming symbiosis and achieved value at the individual level also imparts toward Envitech system development.

6.3 Factors impacting the organization of IS system perspective

The soft and hard factors identified throughout the interviews, either driving or inhibiting the development of the ECO3 and Envitech IS systems are mostly similar. Nevertheless, these driving and inhibiting factors impacted the activities and organization of collaboration distantly in different settings. Institutional (soft) factors like legislations can be recognized as the key catalyzing factor behind IS system initiatives either in the form of a self-organized or planned symbiosis model. The waste legislation of Finland, prioritizing "no landfills" enforced numerous industrial actors to collaborate in initiatives like ECO3. Though the organization of the Envitech system was not directly linked to legislation, yet, the new waste legislation implicated in Finland in the year 1996, compelled municipal

actors to organize waste management activities in a new way. This thinking ultimately led to the development of today's well functioning Envitech ecosystem. Besides, the Finnish policy of attaining an environmental permit to conduct industrial operations functioned as a driver in both of the IS set-ups, as the companies who joined the IS ecosystem received the permit without any complication. The possible benefits to be achieved through being part of the Envitech ecosystem encouraged multiple company actors to collaborate there. Thus, it can be said that following the legislation and policies (institutional factors) city of Nokia actors (public) planned ECO3 while legislation enforced company actors to collaborate on the Envitech area.

Besides, the most important driver in both of the IS arrangement was a specific person which represent social soft factor. This person can be acknowledged as a champion or cata-person, their role has been the most significant in the overall development of the IS process. For the Envitech ecosystem, *Mr. Immo Sundholm was mentioned as the main driver* by many other company actors during interviews. The concept of Envitech area was completely driven by him from the initiation of the idea to the organization of collaboration. Similarly, the main operator or driving agent of the ECO3 ecosystem is *Mr.Sakari Ermala*, assigned by Nokia city to develop the system. However, being responsible as the main operator, Mr. Sakari Ermala has been in partnership with Mr. Harri Kallio from PJH to progress with the ECO3 area. Their mutual understanding and friendship strongly catalyzed the development of the ECO3 area. Thus, the cata-persons in the different ecosystems also support the case categorization mentioned earlier. As Mr. Sakari Ermala is a public organization's actor and Mr. Immo Sundholm is an individual company actor and both of them have driven the organization of the IS system.

Furthermore, social soft factors like trust and co-operation are the most important driving factors to create collaboration among actors. Frequent communication and interaction is the driving force of developing relationship among industrial actors based on trust. As ECO3 system is still in the development phase, it facing challenges to collaborate actors, developing trust among them, and creation of a mindset to share information among company actors. On the other hand, growing trust and co-operation among actors was not mentioned as an inhibiting factor in the Envitech area. Rather, the actors from companies collaborated according to their own interest in receiving mutual benefits. Besides, in ECO3 the actors meet in a monthly meeting to discuss the development opportunity of the platform through sharing ideas. While such measures are rarely followed in the Envitech system that inhibiting the future growth opportunity of the system. To drive the collaboration among company actors the Envitech ecosystem followed more of an informal approach, established Forssa environment club to collaborate company actors to

share ideas. Alongside, the Forssa sub-region actors had a long tradition of business around IS that helped the progress of the Envitech ecosystem.

In terms of technical hard factors like the exclusive location of the IS system surrounding big industrial cities notably attracted company actors to collaborate in the area. The IS systems are established with an objective of offering cost-efficient logistics, reduced procurement cost. However, in the Envitech system, all the company actors are not operating in the same location, yet the benefits achieved through symbiosis has outgrown the transportation cost. Whereas the ECO3 ecosystem has been planned with all industrial actors operating from the same location. Nevertheless, at present, the location of the Envitech system is posing a significant challenge for the network to grow. Over the years the Forssa region became cornered from the industrial zone of Finland, the Envitech system is facing challenges to create business relations due to the high expense of transportation.

The Envitech system being the first of its kind, faced some significant technical challenges in the initiation phase. For example, managing a competent workforce and make people realize the value of symbiosis was difficult during that time. Participating companies in the Envitech system being competitors to each other posing inhibited the development of the area to some extent. Contrastingly the organization of ECO3, did not face such technical difficulties, yet organizing collaboration among actors is still inhibiting the economic growth of the system. The ECO3 ecosystem also involved competitors, yet they are working in co-operation, rather than being competitive with each other for joint development. Another major and common challenge faced by both of the ecosystem actors is related to economical factors like market uncertainty of bio-based products. Consumers are resistant to accept changes and still considers bio-based products as waste. Thus, it can be said that the organization of Envitech system is mostly impacted by *social (soft) factors like cata-person* and *economical (hard) factors like a cost-efficient business* through symbiotic operations. While the ECO3 IS organization activities are impacted by *institutional (soft) factors like legislation, and policies, social (soft) factors like cata-person*.

6.4 Summary of the case comparison

The findings from comparative analysis of the ECO3 and Envitech cases are further summarized in Table 9.

Table 9. *Comparative analysis on publicly driven and company driven IS model.*

	Dimensions	Publicly driven IS model	Company driven IS model
IS Process development	Initiator	City of Nokia (public actor)	Mr. Immo Sundholm from LHJ group individually initiated the concept, the city of Forssa didn't have any big role at the initial stage
	Motivation of initiator	Regional development, bringing sustainability in business operations.	Improving the economic situation of his home region.
	Core relationships	Formed among public sector organizations (Verte, PJH, Tampere University, Nokian Vesi).	Local company actors like LHJ group, Envor Group, Forssan Ympäristöurakointi Oy intiatially joined the system.
	Network organization pattern	Offering platform-based services to collaborate with individual companies into a symbiotic relationship.	Local company actors joined the ecosystem spontaneously.
	Mode of collaboration	A formal approach through meetings, events.	An informal approach toward collaboration, existing relationships.
	Expansion strategy	Planned to serve as an "international pilot and demonstration center" as a CE business model.	Locally organized and expansion of the network is confined to the locality.
	Promotion	ECO3 concept is remarkably promoted to the international actors by the organizers.	Well organized yet less recognized symbiosis platform at the national and international level.
Ecosystem	Ecosystem evolution pattern	Planned symbiosis model	Self-organized symbiosis model
	Central operator	Verte	LHJ group, though not responsible for it.
	Core actor's perspective	Platform company aims to generate profit by selling the "ECO3" concept at the international level and developing collaboration.	To establish an environmental technology business in the locality.
	Intermediaries	Regional authorities facilitating collaboration among company actors from the beginning.	Local business development company functioning as an intermediary at the later phases of ecosystem evolution.
	Eco-innovativeness	Highly innovation ecosystem, SMEs can run pilot projects through ECO3.	Innovation practices are organized at the individual firm level.
	Research and educational institutes	VTT and Tampere University conducting innovative research projects for the ECO3 development.	HAMK and LUKE functioning as a glue to overlook the Envitech system and create new symbiosis opportunities through research projects.
	Operational ecosystem	Four different cycles: nutrient, wood, energy, technical.	Recycling operations: electric and electronic waste, biowaste, contaminated soil treatment (Cavén, 2015).

		Operative process actors will share resources in the same area.	Actors are sharing resources at the Envitech area and some from their individual firms.
Soft and had factors impacting IS organization	Institutional factors	Waste legislation of Finland and policies supported the development of the ECO3 system.	Environmental permit provided by ELY-keskus driven many companies to join the Envitech ecosystem. Frequent changes in legislation inhibit the development of new projects.
	Social factors	Cata-person, Mr. Sakari Ermala. Establishing trust and co-operation among company actors posing a significant challenge. Friendship of Verte and PJH.	Cata-person, Mr. Immo Sundholm. Existing co-operation among companies assisted the development of Envitech system. No partnership, mainly organized by LHJ group.
	Technical factors	Exclusive location has driven company actors to collaborate.	Location of Forssa inhibiting the business network growth.
	Economical factors	SMEs consider “ECO3” a gateway to develop an international business network for individual firm level.	Companies are responsible for their own network growth, success achieved at the firm level add value toward the system to be recognized. Excessive transportation cost.

- ECO3 platform being developed to serve as a pilot and demonstration center of CE activities at the national and international levels significantly escalated the value of the platform toward national-level actors. On the other hand, Envitech is mainly organized by the local level company actors and the formation of business relationships remained confined to the locality. However, at present local business development platform, FYKKI and educational institute, HAMK are promoting the Envitech symbiosis to different national-level actors.
- One of the key features of ECO3 system is that the concept has been highly promoted in the international market with participation in different events. The massive promotion and marketing of the platform at the international level will assist the company actors to get recognized by international actors and grow their business network. Opposite of that Envitech system is a completely localized platform, no promotional activity was identified during the development phase of the platform. The company actors are mainly responsible to grow their business network and marketing activities individually. Therefore, though the symbiosis system is functioning properly, yet many national-level actors are not even well recognized with the platform which inhibited the further growth opportunity of the system.

- ECO3 is providing platform-based services to collaborate actors to initiate business through IS, while local company actors collaborated for the Envitech system because of their own operational need.
- From the emergence process analysis, the key difference between ECO3 and Envitech is that one (ECO3) emerged as a “planned symbiosis model” through public sector (City of Nokia) initiative while the other (Envitech) emerged from company actor’s co-operation as a “self-organized symbiosis model”.
- The central operator of ECO3 is a platform operating company, Verte inaugurated by the city of Nokia, which at present solely organizing ECO3 area and is open for opportunities to develop systems like “ECO3” at other cities of Finland or even at different countries. On the other hand, there is no central actor for organizing, managing, and, development activities in the Envitech system.
- In ECO3 social factors like trust and co-operation have been mentioned as the most significant challenge by the platform company for organizing collaborations among company actors whereas in Forssa the local company actors were known to each other's business process and were already operating in co-operation with each other. Therefore, collaborating company actors to initiate the Envitech ecosystem did not possess any significant challenge due to the small geographical region.
- Over the years different technical factors are posing major challenges toward the advancement of the Envitech system. The Forssa sub-region is located in a distance from the economic growth zone (Tampere, Helsinki, Turku) of Finland, which inhibits the company actors to initiate further symbiosis due to higher transportation costs. However, the ECO3 system is located in the Pirkanmaa region centered around cities of Tampere, Ylojarvi, and Nokia, within a few hour distances from Helsinki and Pori. Hence, this exclusive location of the platform attracted numerous company actors to join the ecosystem.

Referring to the case analysis and comparison of cases it is clearly evident that in ECO3 public sector actors are the most prominent and responsible for organizing the whole system. ECO3 is emerging in an organized manner and different level actors are well recognized with the value of the platform. However, at present, the main challenge for ECO3 is to collaborate company actors for joint operations due to transparency and trust issues. On the contrary, the organization of Envitech area activities is mostly driven by local company actors. The rationale behind this well functioning system is company actors joined in a self-driven way and they are the final decision-makers to bring any

changes in the area. Nonetheless, at the present time, Envitech requires co-operation from public sector actors to promote the area and bring new business partners for further progress of the area. Thus, the above-mentioned categorization of ECO3 as a “publicly driven IS model” and Envitech as a “company driven IS model” is comprehensively justifiable.

7. DISCUSSION AND CONCLUSION

7.1 Key findings

This study aimed to identify the process of building inter-organizational collaborations to create industrial symbiosis (IS) systems. To meet the objectives, this research progressed with the three key research questions. The first research question was: *how does the collaboration process of industrial symbiosis (IS) systems emerge and develop?* To answer the first research question this study approached with a three-phase (emergence, probation and, development and expansion) IS evolution process. The second research question was: *how is the industrial symbiosis ecosystem organized?* To answer the second research question, the actors involved in an IS ecosystem were categorized into two sectors: public organization and private company actors, and their role was further defined. The third research question was: *what is the driving or inhibiting factors impacting the organization of the IS systems?* To answer this the driving or inhibiting factors impacting the organization of IS systems were broadly termed as soft (institutional, social, and environmental) factors and hard (economical and technical) factors.

Following the above-mentioned approaches toward analyzing two different Finnish IS cases (presented in chapter 5) and cross-case analysis (presented in chapter 6) showed that the organization process of IS systems can be categorized into two models: “publicly driven” and “company driven”. The findings from the empirical case analysis (presented in section 6.1 and 6.2) meet the objectives of the first and second research questions at the same time. The categorization of IS models indicates the ecosystem actors who remain dominant in all the development activities at the three different phases of IS process development. Hence, ECO3 located in the city of Nokia is the concrete example of a publicly driven IS model, while the Enviteh, located in the city of Forssa resembles the company-driven approach. Besides, the analysis presented in section 6.3 showed that the organization of IS systems either “publicly driven” or “company driven” is impacted by a similar set of soft and hard factors (either as driver or inhibitor). The key findings on the publicly driven and company driven IS organization process, ecosystem actors, and driving and inhibiting are further discussed elaboratively.

In a “*publicly driven model*” the initiator of the IS concept is the local authorities to be specific the municipalities. The municipal actors consider IS as an opportunity for regional development with sustainable business practices. Thus, during the emergence phase of this IS model the municipal actors progress with proper planning on how to

develop the ecosystem further. The initial fundings to develop the IS system is also managed by municipal actors. In this model, the municipal actors might inaugurate a platform development company to co-ordinate all the activities for the system development. For instance, in ECO3, the city of Nokia opened Verte which is the main operator of the ECO3 system at present. In an IS system the core network is generally organized among waste management companies, energy companies, research institutes, and in collaboration with the platform company. As waste is the key source of raw materials, later converted into an energy source; it is quite practical to involve such actors from the emergence phase of the IS process development. Nevertheless, the platform development company function as the central operator in this publicly driven IS model and play a quite diverse role in different phases of the IS process development.

With the formulation of the key concept and planning on the operational processes at the emergence phase, the central operator of the publicly driven IS model focuses on connecting local companies in the ecosystem during the probation phase. Hence, the central operator functions as the main integrator or media to create connections among local company actors, as at the beginning of this phase companies only share information with one another through this central operator. Gradually, the local company actors cooperatively connect with each other and establish symbiotic linkages based on trust. However, the central operator remains responsible for managing fundings from national-level organizations to develop the IS system and also expects to serve the IS model as a pilot and demonstration center. Hence, the actors involved in the three different phases of a publicly driven IS model and the activities are illustrated in Figure 16.

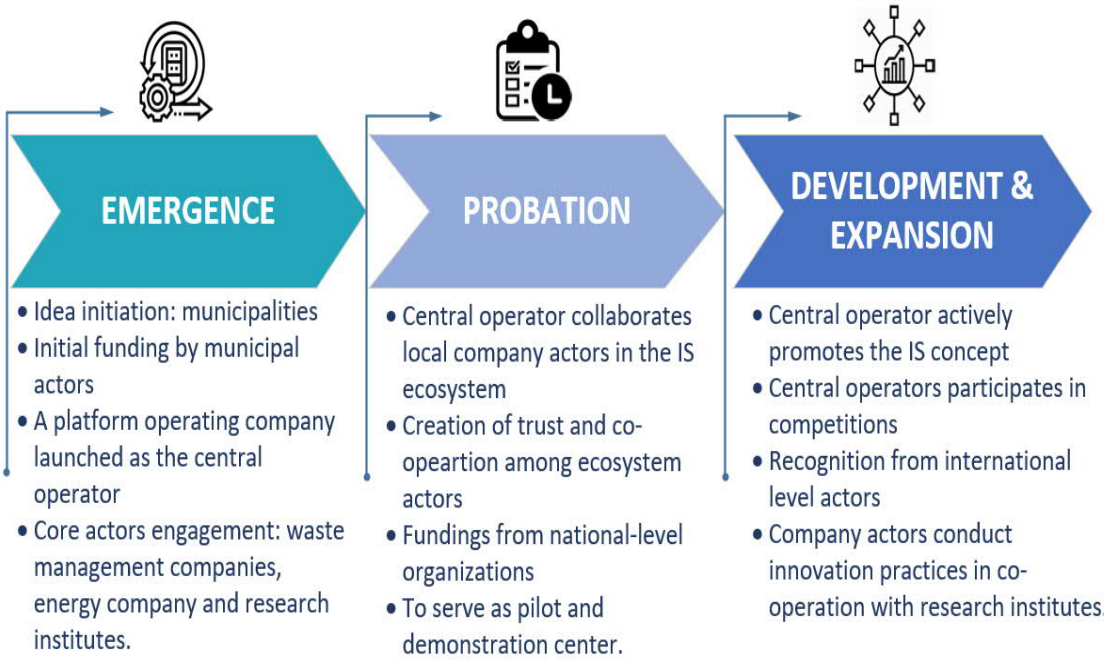

Figure 16. *Publicly driven IS model phases.*

As mentioned in figure 16 during the development and expansion phase the central operator mainly prioritizes promoting the IS concept to national and international level actors with participation in several events and competitions. Such actions intensify the value of the IS system, attract financing organizations, and other regional institutes to co-operate for future advancement of the system. Getting recognition from international actors, also attracts local companies to join the IS ecosystem, as many of them consider the IS system as a way of finding new business partners and credibility from international organizations. While some companies just remain a part of the IS ecosystem to keep themselves updated with the local businesses. Furthermore, to ensure the sustainability of the IS system, the company actors conduct innovation practices in co-operation with each other and research institutes. Thus, although the "publicly driven IS model" incorporates actors from both the public and private sectors, yet a central operator (public sector) remains dominant throughout the entire IS process development.

On the other hand, the IS emergence phase of a *"company-driven model"* initiates with the biggest visionary, from local company actors. This visionary role can be played by an individual person or even it can be a group of actors. For instance in Envitech, Mr. Immo Sundholm from the LHJ group was such a person, who initiated the area with a vision to improve the economic situation of his home region. However, there is *no central operator* who is responsible to organize all the activities of a "company driven model". Rather the initiators of the concept need to function as the *central organizer* during the

early development phases until the symbiotic linkages are established. Usually, this model doesn't require prior planning for the operational processes, rather based on the business area and requirement of different actors the ecosystem is organized. For instance, the Envitech ecosystem in Forssa was mainly organized based on environmental companies operating in the area. Similar to the publicly driven model, waste management companies, energy companies, and research institutes are the core actors for the operative process of the company driven model and these relationships need to be established during the emergence phase. The initial fundings to organize the IS system is also managed by the central organizer from local, regional, and national level actors.

During the probation phase of a company driven IS model, the local companies operating in the same geographic area mostly join the IS ecosystem. Alongside, the central organizer being a local company actor, is already well-recognized with the companies operating in the locality. Therefore it is comparatively easier for him or her to gain the trust of other local company actors and should possess the competencies to make them realize the value of symbiotic operations. Besides, the companies operating in a locality are usually well aware of the business operations of other companies and easily find opportunities to co-operate. Thus, the local company actors spontaneously get involved in the IS ecosystem and their existing business partners also become a part of the wider IS ecosystem. Moreover, the local companies join the ecosystem based on their own operational need, and the co-operation established is always two-ways.

Nevertheless, the two-way co-operation or symbiotic linkage is not always established based on resource exchange. For instance, in Envitech a two way-cooperation was established between Envor Group and Saint-Gobain. A direct biogas pipeline was constructed from the Envitech area to Saint-Gobain operating plant. The pipeline was constructed in co-operation with Saint-Gobain and Envor Group, however here Saint-Gobain is only purchasing the biogas from Envor Group not sharing any materials to create a symbiotic linkage. Yet, Saint-Gobain is an important actor in the Envitech ecosystem. To foster the collaboration among company actors the local authorities from public sectors might take initiatives like opening an environmental club. It is noteworthy that the public sector actors do not have any significant role in the actual development of the IS system, rather they just take the position of intermediaries to foster company actors' collaboration. Hence, the actors involved in the three different phases of a publicly driven IS model and the activities are illustrated in Figure 17.

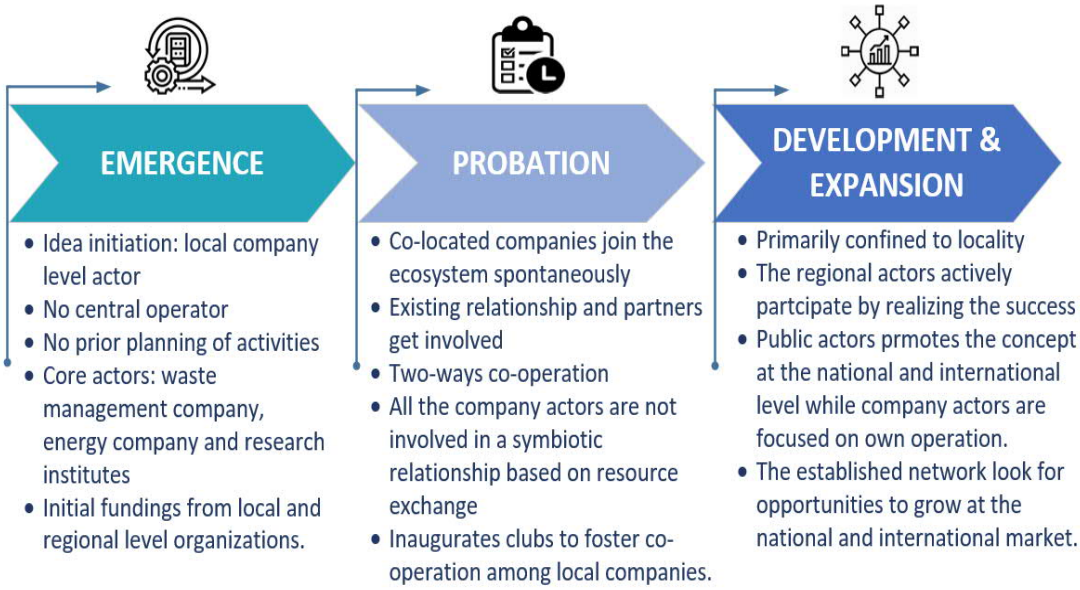

Figure 17. *Company driven IS model phases.*

As described in figure 17 the development and expansion phase of an IS model mainly focuses on expanding the business network. In the case of a publicly driven IS model, the company actors involved in the IS ecosystem are mainly focused on their own business operations and the system remains confined to the locality. However, the success achieved through a company-driven IS model encourages the local and regional authorities to collaborate in the ecosystem at this phase. These local and regional authorities promote the IS system to national and international level actors. Hence, the public sector actors mainly function as intermediaries to find new partners for the existing network. While the company actors are the final decision maker to bring any changes in the system and to create new symbiotic linkages.

Nevertheless, both the publicly driven and company driven IS model comprehends a similar set of soft and hard factors that either drive or inhibit the organization of the IS system activities. The key driving force behind organizing any IS process indicates towards *social (soft)* factors like the human, personal, or psychological value of a person, whose own determination and vision results in developing the system. For instance, *Mr. Immo Sundholm (from LHJ group)* was driven by his personal value and interest to improve the economy of his home region through the Envitech system while in ECO3 *Mr. Sakari Ermala (from Verte)* is functioning as the main driving force to organize all the activities. These people can be marked as *cata-person (social soft factors)* who organize the IS system. Besides, *social* values like *trust and co-operation* are core factors of initi-

ating any business relationships. To develop trust actors need to frequently communicate with each other. Most importantly the actors should *share a joint vision* to develop the system and every actor involved in the ecosystem should receive equal value by operating in the system. Besides, *institutional (soft)* factors such as *legislations* and *policies* significantly influence company actors to collaborate in IS systems. For example, both in the ECO3 and Envitech area, the environmental permit authorized by ELY-keskus to conduct different waste handling business has driven company actors to operate in the area. Furthermore, *economical (hard)* factors like the *growth potential of the business network* at the national and international level is a great way to drive company actors to join the system. While *technical (hard)* factors like *location* is another important one, as the key idea is that the co-located companies will share effluents to reduce *transportation and waste handling cost*. Thus, it can be acknowledged that *soft factors like social and institutional ones* are the important ones to initiate symbiotic relationships among ecosystem actors while *hard factors (economical and technical)* are the important ones for business development through the IS systems.

However, inconsistent changes in *institutional factors (soft)* like *legislation* and *bureaucracy* present in public organizations adversely slow down the progress of any new project. *People need to change their attitudes (social factor)* toward bio-products, *expand the market* of such products (*economical factor*), even government cam implicate regulations *(institutional factor)* to increase the utilization of bio and circular economy based products and services. Till now consumers and several actors from companies consider bio-based products as waste. Nevertheless, the key inhibitor of a company-driven model is that all the ecosystem actors are mainly focused on their own individual level operations, there is *no central actor (social soft factor)* to manage the companies and open more opportunities. While the development of a publicly driven model is inhibited due to the absence of *social factors (soft)* like trust and co-operation among company actors, and they are *resistant to share information*. Therefore, maintaining transparency, where all the ecosystem actors are aware of the process will open more opportunities for co-operation. Therefore it can be said that the key inhibitors of a “publicly driven” model are related to *soft factors* like legislations (institutional factor) and people's attitude (social factor) while the progress of a “company-driven” model is inhibited due *to social (soft) factors* like the absence of *central operator* to ensure business expansion.

Thus, based on the above-mention findings it is justifiable to say that the IS systems can be organized by following the approach of a “publicly driven” or “company driven” model which answer the first and second research question at the same time. The key findings

from the publicly driven and company driven IS models with soft and hard factors impacting both kinds of IS organization activities are summarized and illustrated in Figure 18.

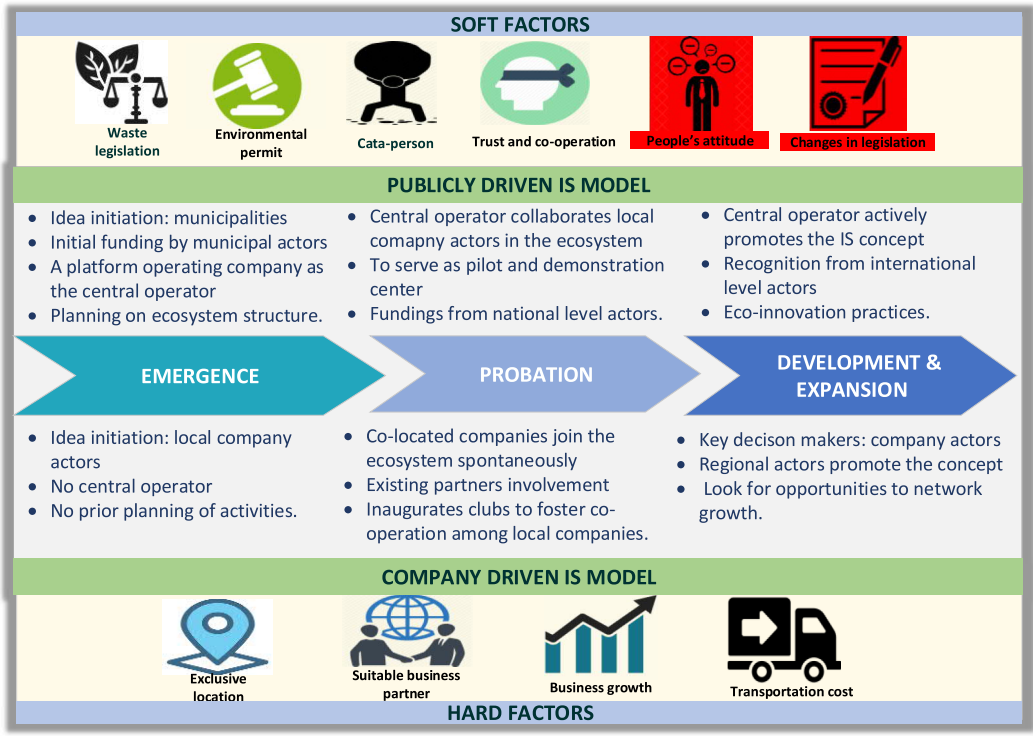

Figure 18. *Publicly and company driven IS evolution phases with impacting factors.*

The factors which can drive the development of the IS systems are related to social (soft) factors like trust and co-operation, cata-person, institutional (soft) factors like waste legislation, environmental permits, and economical (hard) factors like business development opportunities, transportation cost and technical (hard) factors like exclusive location. The inhibiting factors (marked in red in figure 18) faced by IS ecosystem actors are mostly related to social (soft) factors like people's attitudes and institutional (soft) factors like inconsistent changes in legislation. It is further recommended that the steps followed in a “publicly driven IS model” is more implacable in a new IS system while the “company driven IS model” process is more implacable to transform existing symbiotic linkages to a wider level or to an eco-industrial initiative.

7.2 Theoretical contribution

This research adds value to the existing literature on the collaboration process development of the IS system and the co-evolving ecosystem by conducting an empirical analysis of IS cases. The IS literature from a processual dimension still lacks an in-depth understanding of the evolution phases of an IS system and how different activities are organized (Walls and Paquin, 2015). The empirical analysis on two completely different yet enriched IS cases provide profound insights regarding the events occurring at the three different phases of the system (Doménech and Davies, 2011) and the importance of those activities to initiate collaboration and development of an IS system. In addition to that, a detailed analysis of the IS ecosystem structure generates pragmatic knowledge of how the ecosystem is co-evolving at the different phases of the evolution process, and the role of different ecosystem actors, and expectations from the system. Thus, the multiple case analysis with a processual approach (Boons, Spekkink and Jiao, 2014) provides a better understanding of the prior learnings on the IS ecosystem and its different organizational clusters. Furthermore, the case analysis offers a broader spectrum of soft and hard factors either driving or inhibiting the development of an IS system indirectly or directly from a contextual point (de Jesus and Mendonça, 2018).

Besides, a comparative approach toward analyzing the cases demonstrated that the emergence of an IS system can follow a publicly driven or a company driven approach which adds value to existing knowledge on the IS process development. Nevertheless, this IS organizational perspective matches the theoretical findings on the IS categorization model in a way that the publicly driven approach follow the planned IS model (Lowe, 1997) while the company driven model is based on the self-organized IS model (Chertow, 2000; Lambert and Boons, 2002). In the “publicly driven model” the public organization actors representing municipalities, local and regional business development platforms, educational institutes, regulatory institutes are mostly dominant throughout the entire IS process development phases. Though the findings from the literature suggest that the public sector actors (Herczeg, Akkerman and Hauschild, 2018) are highly incentivized in organizing the IS systems to bring environmental sustainability (Boons, Spekkink and Mouzakitis, 2011; Afshari *et al.*, 2018), yet the empirical results contradict with it to some extent. Hence, the public sector actors are motivated to organize the IS system to improve the regional economy through the creation of new employment opportunities, new businesses, and conduct business operations in an environmental friendly way. Even collaboration among company actors is arranged by public organizations.

On the other hand, the “company driven IS model” illustrate quite an opposing view from the synthesized literature. The public organization actors are rather absent in this model during the emergence and probation phase of IS process development, and even if actors like regional business development platforms, municipalities remain a part of the ecosystem their role is insignificant in the organization of the IS system. Hence, the co-located company actors are the core of this ecosystem, yet those are actors are mainly focused on individual-level business development, and how collaboration with other companies generate value for them. Thus, the findings from empirical cases conflict with the synthesized framework (presented in section 3.4) to some extent, as it was mentioned that the IS systems in the form of an EIP are mainly organized by the active participation of both public and private company actors. Where the empirical findings (presented in chapters 5 and 6) indicates that in the development of the IS system, either public organizations or just company actors take the lead roles.

The most promising contribution of this multiple case study analysis is the presence of a key actor identified in both of the systems, who can be defined as a cata-person (Sakr *et al.*, 2011), champion or hero (social factor) driven by personal value, considering the IS system development as his/her own responsibility is the key requirement of any IS system. This type of actor initiates the process, connect actors, and function as the main driving force for the overall system development. Furthermore social factors like trust and co-operation (Heeres, Vermeulen and De Walle, 2004; Gibbs and Deutz, 2005), frequent interactions, and institutional factors like legislations are the utmost drivers of initiating collaborations among company actors compared to economic factors. Thus, the actualized information from this research significantly contributes to the lacking knowledge of an IS system from an organizational and managerial dimension. The study findings specifically, the drivers and inhibitors will be beneficial to research fields like circular economy, environmental sustainability, and industrial actors operating in those fields. Besides, purposive sampling for case selection and focusing on priority to choose business actors to be interviewed assisted in structuring the IS ecosystem, the diversified role of them, and the integrated driving and inhibiting factors of the IS system.

7.3 Practical implications

Industrial symbiosis systems being acknowledged as a collaboration platform of organizational clusters from different sectors such as regulatory authorities, private companies, research and educational institutes, local and national governmental authorities; this study aims to provide valuable implications that will assist all different stakeholders to

develop an accomplished and well-functioning IS ecosystem collaboratively. Furthermore, Finland set the strategy to be a pioneer in the field of the circular economy within 2035, by introducing a transition in the present linear economy model and conserve natural resources (SITRA, 2016). Initiatives like IS offers an excellent opportunity to organize business activities through the implication of CE principles to bring sustainability. With an aim to be a global leader in the field of CE, Finland already organized multiple IS systems at the locality in different regions. Nevertheless, only a few of those initiatives have been able to meet the end objective and many of those are still in the development phase. Alongside this, from the empirical analysis, it is notable that the CE concept is still a buzzword among a majority of the practitioners and only a fraction of actors are organizing activities around it or integrated the concept in actual business operations. It's high time, the stakeholders involved in the process need to shift their mindset, recognize the potential of business through co-operation, and frequently participate in IS initiatives which will bring competitive advantage in the long-term.

As mentioned earlier, the majority of the IS initiatives in Finland is still in the development phase, therefore the actualized result from this study could be beneficial in those cases. The empirical analysis of the IS ecosystem actors with varying roles and understanding the significance of each actor's contribution will be beneficial and can be followed while structuring a new IS ecosystem. Furthermore, the outlined driving factors from two different symbiosis cases need to be taken into consideration by the organizing agency of the system. On the other hand, the demonstrated inhibiting factors, not necessarily need to be avoided always, rather it needs to be modified or can be a specific need to organize the system which is unavailable at present. Therefore, these factors need to be handled and solutions need to be proposed by policymakers, regulatory authorities, company actors or even the local people can bring a change. By analyzing a publicly driven and a company driven IS model, this study suggests that IS system organization needs to be nurtured with an impactful collaboration of public organizations and private company actors. Therefore, this study provides implications for all the IS ecosystem actors (from different organizational clusters) which might be beneficial in organizing a new IS facility or can be implicated at the existing one. Hence, the first practical implication will be,

1. IS systems should be a collaboration platform of private and public organizations with a joint vision of conducting economic activities in an environmental friendly manner.

In accordance with the first implication, it is further suggested that the role of each actor throughout the development process needs to be clearly defined and act according to that. For example, municipalities can be the initiator of the concept as IS systems are

organized in a locality and significantly contribute to the local economic development. Municipalities share a strong connection with the local people and regional institutes, can assist the network development of the system. Although private companies and public organizations have different organizational structures and values, they need to develop a co-operative mindset, organize, and plan the activities in accordance with the three phases of an IS system development. Besides, all the ecosystem actors have their own individual level operations, will highly prioritize the activities of their own operations. Specifically, the top managers of private companies have a tight schedule, will merely focus on the development opportunities of other companies involved in the network. Therefore, an IS system will require a platform company that will be the central or main operator of the system. Hence, the second implication for municipal actors,

2. Inaugurating a platform company and hiring a competent person responsible for developing a well-functioning and systematized IS facility.

The key driving force behind building collaborations and organizing activities toward IS system will be this platform company to be specific, a particular individual, designated as CEO of the company. This person should incorporate the quality of a great leader, trust-worthy, and have a visionary role to influence others to participate in the system. This individual needs to be a risk-taker, have the ability to realize the future market potential and possess the expertise and knowledge to handle critical situations at least during the early development phases. Through his/her excellent competency, impactful personality, and networking capability, the person will manage to collaborate with a broader set of actors to facilitate the collaboration process. Besides, this person will be responsible to organize promotional activities to enhance the system values, define what actually needs to be done, and most importantly integrate private company actors as those are the core of the operational process. Thus, the third implication is referred to the platform company operator,

3. The actual need is to interact with different stakeholders to discuss how the common vision can be reached and what kind of benefits can be achieved through collaboration. Regular meetings enable effective networking, finding new partners, as well as sharing best practices.

Acknowledged through the empirical analysis, trust and co-operation among ecosystem actors is the main driver to initiate a symbiotic relationship. Developing co-operation and trust among ecosystem actors will require having frequent interactions and communications. Here, the platform company needs to take responsibility for organizing events, seminars, and meetings to connect the company actors with each other. This will also

provide the opportunity for networking and the ecosystem actors will realize the value of the IS system. Nevertheless, the private company actors need to be pro-active, be more open to sharing information as it might create new opportunities for others. In addition to that, the IS ecosystem actors need to maintain transparency throughout the process, share ideas for the whole IS system development, communicate and move forward with a joint vision of the IS system. Therefore, the fourth implication for top managers of companies is,

4. Be open to share ideas, information regarding resources (waste flow data), work in alignment with the ecosystem actors to gain a competitive advantage for the future.

In an IS system, the waste or effluent of one company is considered as a resource for others, therefore, making the waste flow data visible to others, the company is not losing anything rather might create new businesses. Here, the regulatory authorities can play a significant role to create linkage, as the companies are obliged to record and send the waste flow data to them. The regulators can provide flexibility for organizations and encourage businesses with waste materials. In addition to that regulators, policymakers can formulate new legislation in collaboration with company actors to recognize the need of supporting bio and circular economy activities. Besides, the empirical study highlighted the point that people are resistant to changes and manifest a negative attitude toward bio-based products. In this regard, the regulators can play a significant role to bring changes and the fifth implication is,

5. Legislations to support bio & circular economy business and implicating new rules to increase the use of the end products are needed.

Furthermore, Finland being a relatively small market with a population of 5.5 million people only, the greatest challenge of such any IS system is to ensure scalable business opportunity. One approach could be connecting the IS networks from all over the country, which should be well-organized in connection with the economic zone of the country. For instance, Tampere is the second-largest industrial city of Finland, with a good transportation facility with Helsinki, Pori, Turku which developed the significance of ECO3 as a business platform exceptionally. The IS platform should also incorporate the possibility of international linkage. Therefore, an IS system should be developed in a way that will offer scalable business opportunities toward all the ecosystem actors to sustain for the long-term, and once the industrial scale business opportunity is there the company actors will drive for collaboration themselves. Thus, the sixth and final implication is,

6. The initiation of an IS system is not sufficient itself, the business and growth opportunity must be bigger and scalable.

To conclude, concepts like IS, circular economy are still in the development phase at a practical level. A successful practical implication of the concept would require persistent co-operation with research institutes and academics to conduct innovation practices, provide necessary fundings, developing a skilled workforce. Nevertheless, Finland to be a global leader in CE practices would require building collaboration among multiple stakeholders with a shared vision toward organizing business practices through IS.

7.4 Limitations and future research scope

Although this research provides a robust structure on the industrial symbiosis ecosystem with the exploitation of a broad range of driving and inhibiting factors impacting the organizational activities of the IS system, yet the research confronted some ceratin limitations due to the chosen methodology and context. This research approached with a multiple case study method with a purposeful sampling of two different IS cases from Finland. Both of the cases are rich in information and significantly important for Finnish national-level development in CE practices. However, this research lacks understanding of the IS systems from the international level, how other countries organized the IS ecosystem, what kind of policies and legislations have been implicated to facilitate IS organization, and what is the ecosystem structure. Learnings from the international level IS systems regarding success and critical factors can be further compared with the cases from Finland.

Next, this research was designed to explore the development activities of an IS system from a processual dimension and tried to identify the events or milestones that radically brought a change in the IS system development. However, during the empirical analysis, it was difficult to point out all the events due to the limitation of data sources. The emergence of an IS system, generally happen over a long period of time, and during this time the ecosystem structure evolves, even the actors from different organizations also change over the period. Therefore, all of the present ecosystem actors are not aware of the storyline or events that assisted the development of the IS system, which was the objective of first research question. Besides, due to the limitation of human memory even the actors who were involved in the ecosystem from the beginning could not mention all the events with the exact time. Furthermore, the amount of secondary resources were also limited. In the case of ECO3, still being in the development phase all the required information is not available. On the other hand, in Envitech though there is a significant

amount of secondary resources, yet sometimes provided conflicting information. The Envitech system being locally organized without much recognition of the platform, it posed a significant challenge to get access to the data sources. In addition to that, it was difficult to access information on the exact timing of actors joining the ecosystem, such accuracy would be beneficial to map the ecosystem and understanding the importance of each kind of actor's involvement throughout the process.

Defining the boundary of ecosystem actors to be analyzed is a critical choice, as all the actors involved in the ecosystem hold a different opinion and perspectives on the system, and interviewing all of them might provide a much deeper understanding of the studied systems. While the number of ecosystem actors to be interviewed was narrowed down due to the time concern and thus the perceived result is based on a fraction of actors interviewed. Moreover, getting access to the top managerial authority was a difficult task, and some actors considered interesting for the research was not willing to participate. Qualitative multiple case study method, with interviewing different set of actors consumes a large amount of time (Baxter and Jack, 2008), and all the interviews not necessarily result in generating quality data. Nevertheless, all the participating actors were very friendly, although some of them were hesitant to participate due to language issue (as interviews were conducted in English), yet the interviews went extremely well and resulted in collecting satisfactory insights on the cases. Personal interviews were utilized as the main data source throughout the research. The interviews were conducted by following a semi-structured pattern, according to the researcher's understanding, the questions were modified based on the role of the actor in the ecosystem to be interviewed. Nevertheless, the questions were mainly focused on actors engagement the IS system development, while exploration of individual company activities to some extent might provide a deeper understanding of the thought process behind each movement.

Conducting face to face interviews always result in providing insightful information and the actual feeling of the interviewee regarding a topic with analysis of gesture, posture, expression during the interview. Even, a competent researcher can develop a connection with the interviewed person through physical presence and always results in collecting more detailed information. However, the pandemic of Covid-19 limited the opportunity of face to face interviews specifically for the Envitech case, it was even difficult to organize a physical visit to the area. Due to the exploratory nature adapted to analyze the IS system, in total 16 interviews were conducted which resulted in a significant amount of data to be analyzed. As the final result was constructed based on researchers' understanding and interpretation from different data sources, this might forsake some human error.

Although the insightful and interesting findings from the comparative analysis of cases offer a great possibility for future analysis, aligned with that the above-mentioned limitations also indicate further research dimensions to be explored. The first suggestion would be analyzing the unexplored dimensions of the collaboration process development toward IS systems. This research predominantly studied the motivations, expectations, and incentives of the different ecosystem actors to participate in the system. A deeper understanding of the relationships among ecosystem actors needs to be studied by organizing group discussions with different actors. Besides, the role of facilitators to initiate collaboration among company actors, what kind of agendas are followed, and developed by those organizations can be beneficial in the organization of any IS systems (Jarre *et al.*, 2020). Thus, a deeper analysis of the IS ecosystem actors and how they co-operate will be beneficial toward the initiation of any IS system.

This research mainly analyzed the human layer aspect of organizing the IS system, while broader scope can be visualized by demonstrating the scope of materials sharing. Thus, further research can be conducted to realize the significance of material flow data to initiate new relationships. In this aspect, the role of digital technologies providing information on material flow data will be an interesting aspect to be researched further, even the role of a digital platform to connect company actors need to be exploited (Yeo *et al.*, 2019). The environmental sustainability dimensions achieved through IS systems can be researched further, which will help to gain attention from international level actors. If measures for a reduction in carbon emission level through IS systems can be introduced it will significantly elevate the value of such platforms.

Furthermore, the inhibiting factors reflected from the publicly driven and company driven IS model need to be taken into consideration. The inhibiting factors mentioned through the cases not necessarily to be avoided while developing an IS system, rather it requires finding a solution on how to improve those issues. For example, the findings from the empirical study highlight the company actors are resistant to share information. So, it will be highly beneficial to conduct an analysis specifically focused on company actors who are not involved in any IS ecosystem, yet conducting a sustainable business operation. Through such analysis, what is the thought of company actors regarding IS systems, and what kind of factors or facilities might drive them to join such an ecosystem can be further analyzed. Besides, an interesting point from the research was found that legislations can function as both drivers or inhibitors. Further research agenda can be developed to identify the key role of legislations in inaugurating IS systems and what kind of changes are needed in policies to thrive development of such systems. Concepts like IS are getting popular worldwide to fight climate changes, introduce sustainabilities, and move toward

policies like zero waste. Therefore, researches on such agendas will be beneficial for Finland to stay ahead and be a forerunner of sustainable development activities globally.

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APPENDIX A: INTERVIEW QUESTIONS

This appendix represents the set of interview questions that were utilized in this research.

Introduction part:

1. Is it okay if we use the information from this interview session for a research purpose?
2. Do you mind if I record the conversation?
3. Description of the operation of your organization? What is your specific role or responsibility in this company?

Company/individual level:

4. What kind of/is there any CE or sustainability practices do you have in your organization at present?
5. What do you consider as driver/enabler of such CE practices in your own organization?

Collaboration level: structure with incentives

6. How your organization becomes part of this platform? What are the main motives of your company/organization to join this platform?
7. How do you see the collaboration process has emerged from this platform? and do you consider that the structure has been evolving over time?
8. Are there any specific milestones/events that you would like to mention that helped the overall progress of the area?
9. What will be the role of your organization in the development of this platform?
10. What are the expectations from this platform?
11. With which organizations your company is currently working in the area?
12. Do your organization have any specific role to collaborate with other organization/companies in this network?

Driver and inhibitor:

13. Regulative: Is there any regulative which accelerate the process of collaboration for CE? or inhibits the process

14. Mode of operation: How about the main operators or management team? Do you consider them perfect for the creation of this platform? or do they need any changes?
15. Organizational value: Is there any specific organizational value that actually driven/enforced you to join the platform?
16. Business: What is the business opportunity? Do you consider participation in this project will help to grow your network and how?
17. Environmental: What kind of benefits can be achieved?
18. Public sector: role of public actor to create the collaboration
19. Technology: Is there any specific technology or tool that helps to create such a platform?
20. Future: What do you think is missing or what can be beneficial, or must be needed to accelerate the collaboration process for IS?
21. At present, what are the main challenges to create collaboration for this platform? or what inhibits CE practices? or what slows down the process?