Matti Rissanen

# ECOGAME AND ECOSYSTEM PROFILER: SOLUTIONS FOR BUSINESS ECOSYSTEM MANAGEMENT

ACTA UNIVERSITATIS LAPPEENRANTAENSIS 1006

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Acta Universitatis
Lappeenrantaensis 1006

Supervisors Professor Timo Kärri
LUT School of Engineering Science
Lappeenranta-Lahti University of Technology LUT
Finland

D.Sc. (Tech.) Tiina Sinkkonen
LUT School of Engineering Science
Lappeenranta-Lahti University of Technology LUT
Finland

D.Sc. (Tech.) Antti Ylä-Kujala
LUT School of Engineering Science
Lappeenranta-Lahti University of Technology LUT
Finland

Reviewers Professor Saku Mäkinen
Faculty of Management and Business
Tampere University
Finland

Associate Professor Heide Lukosch
HIT Lab
University of Canterbury
New Zealand

Opponent Research Manager, Docent Katri Valkokari
Foresight and data economy
VTT Technical Research Centre of Finland
Finland

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# Abstract

**Matti Rissanen**
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Business ecosystems are complex dynamic systems that are yet to be profoundly studied. As interconnectedness between companies and organisations increases, there is a need to improve the understanding of the dynamics involved in business ecosystems, and conventional research methods are not able to capture everything. Therefore, new solutions are required for both studying the nature of business ecosystems and aiding practitioners in managing them. The nature of business ecosystems consists of static and dynamic parts. Static nature is a presentation of the structure of the ecosystem and its actors in a single point in time. Dynamic nature considers the co-evolution of the ecosystem and its actors through their co-creation activities.

This thesis presents EcoGame and Ecosystem Profiler: two solutions that are used to solve problems in the field related to collaboration in multilateral relationships, and understanding of the structure of the ecosystem companies take part in. These topics fall under ecosystem patterning and management. The emphasis on Ecosystem Profiler is to create a static profile showing the ecosystem value proposition, relevant actors, their connections and positions, and relevant individual company information. EcoGame simulates collaborative decision-making processes in the multilateral relationships of real business ecosystems. Through gameplay, EcoGame gathers data on the dynamics related to collaborative relationships within ecosystems. The joint use of the solutions aims at studying and improving the performance of ecosystems by incorporating a created ecosystem profile within EcoGame for the ecosystem actors to play.

To create the solutions, this thesis adopts the Design Science Research (DSR) approach. The solutions draw inspiration from existing solutions used in other fields. The created solutions are tested and proven in a context but the final phase of DSR, evaluation and validation of the solutions as individual and jointly used generalised DSR artefacts, is done in further research. DSR allows the utilisation of a variety of research methods throughout its multi-phase cyclical process adopted in this thesis. Relevant research results can emerge from each phase and cycle while the overall process of improving the designs towards validation continues.

The main contributions of this thesis are the two DSR solution artefacts, EcoGame and Ecosystem Profiler. Through the use of the solutions, this thesis contributes to the knowledge bases of each solution, mainly consisting of literature on ecosystem management, and specifically collaborative decision-making in multilateral relationships. Managerially, they contribute to making the ecosystem structure understandable and building or improving collaboration within ecosystems. Wider contributions to ecosystem patterning and performance comes as the solutions are individually and jointly validated in further research. This thesis answers the call to create understanding on the dynamics involved in business ecosystems in addition to the understanding of the static structure that previous research has concentrated on.

**Keywords**: business ecosystem, patterning, management, performance, static nature, dynamic nature, design science research, solution, profile, serious game

# Acknowledgements

My research work began already when I started my master's thesis with the $C^3$M research group, and I continued with doctoral studies right after finishing my master's degree. I took this doctoral thesis and the work as a junior researcher as a four-year project which now has come to its conclusion. During this project of mine I got to travel a lot, work in intriguing research projects, organise events, and meet a lot of people. At the end of the project, it seems that I have said 'yes' far too many times looking at my calendars but it all contributed to a unique work experience full of learning new things. I do not think I could have had it anywhere else.

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Finally, thank you my family and friends, and most of all my wife Tiina. You may not have been directly involved with my work, but you have offered distractions that have been crucial for my well-being during busy times at work.

December 2021

Matti Rissanen

# Contents

# List of publications

This dissertation is based on the following papers. The rights have been granted by the copyright owners to include the papers in the dissertation.


I. Rissanen, M., Metso, L., Elfvengren, K., and Sinkkonen, T. (2020). Serious Games for Decision-Making Processes: A Systematic Literature Review. *In: Liyanage, J., Amadi-Echendu, J., and Mathew, J. (eds) Engineering Assets and Public Infrastructures in the Age of Digitalization.* Lecture Notes in Mechanical Engineering, pp. 330–338. Cham: Springer.

II. Ylönen, N., Rissanen, M., Ylä-Kujala, A., Sinkkonen, T., Marttonen-Arola, S., Baglee, D., and Kärri, T. (2021). A Web of Clues: Can Ecosystems Be Profiled Similarly to Criminals? *International Journal of Networking and Virtual Organisations*, 24(4), pp. 347–373.

III. Rissanen, M., Sinkkonen, T., Kärri, T., and Ylä-Kujala, A. (2021). Multilateral Collaboration in Ecosystems - Studying and Improving with EcoGame. *In the proceedings of ISPIM Connects Valencia 2021, Valencia, Spain, 29.11.-1.12.2021*.

IV. Rissanen, M., Metso, L., Sinkkonen, T., and Kärri, T. (2020). Recognizing Life Cycle Benefits of Real Time Fatigue Monitoring for Ecosystems. *In: Ball, A., Gelman, L., and Rao, B. (eds) Advances in Asset Management and Condition Monitoring.* Smart Innovation, Systems and Technologies, 166, pp. 417–428. Cham: Springer.


## Author's contribution

I am the principal author and responsible for conducting the research and writing the article in publications I, III and IV. In publication II, Ninni Ylönen was the principal author and responsible for writing the initial manuscript. I took over the correspondence for the paper before publication and was in charge of revising the paper for publication. We worked together with Ninni Ylönen to develop the research idea, and the work reported in publication II is based on her master’s thesis.

# 1 Introduction

## 1.1 Research background and motivation

The seminal work for defining business ecosystems comes from Moore (1993) as he suggests that a business ecosystem consists of companies from multiple industries. The companies and other stakeholders in a business ecosystem, the ecosystem actors, can together create more value to customers than individually possible (Clarysse, et al., 2014; Moore, 1998). The goal of a business ecosystem is to deliver a common value proposition to the end customers while maintaining competitiveness against other ecosystems (Moore, 2006; Adner, 2017; Mäkinen & Dedehayir, 2012). The concept of an ecosystem in business context and its definition by Moore are derived from ecology, first defined by Tansley (1935, p. 299) as a complex of organisms in an environment from which they cannot be separated. Thus, forming a physical system, an ecosystem.

Ecosystem in a business context is not the first type of collaborative inter-organisational structure but it is one of the more complex ones. Forrester (1958) introduced the idea of strategic management of business flows between different company functions. This would mean management of inter-organisational relations when the functions connecting business flows are organised by different companies. In the 1980s, logistics management evolved into supply chain management, which covers the whole product chain from raw material suppliers to the end users of products (Houlihan, 1988). Porter (1985) introduced the value chain which divided company functions such as marketing, research, and production into value creating activities. It is not uncommon to have those functions in different companies making the value chain an inter-organisational structure as well. Supply and value chains are linear structures where flows are between two functions. Adner (2017) discusses other approaches to interdependency between actors, such as platforms (Gawer & Cusumano, 2002), networks of learning (Powell, et al., 1996), open innovation (Chesbrough, 2006) and more. Value network is an approach that considers that the hierarchical structures can branch out due to the value created by a single product or actor being different for different customer groups (Christensen & Rosenbloom, 1995). A value network can as a map of actors look like a business ecosystem but, like in most of the other listed approaches, the flows or relationships between actors are mainly bilateral. The value network also focuses on the competitive advantage of the individual companies branching out to new customer values (Christensen & Rosenbloom, 1995), whereas business ecosystems pursue competitive advantage through providing value in collaboration. Lusch et al., (2010) however, do emphasise service co-production and value co-creation between actors in value networks and note that value networks can be thought of as service ecosystems consisting of multiple, even competing, supply chains.

The value a business ecosystem delivers is generated through co-creation of the ecosystem actors (Pera, et al., 2016). Value co-creation as a term originates from value networks and value chains (Allee, 2002). A value chain can also be seen as one part of Moore’s (1996) presentation of the structure of a business ecosystem (see Figure 1.1).

Therefore, the concept of a business ecosystem is closer to value chains and networks than replacing the concept of industry (Peltoniemi & Vuori, 2005). The purpose of Moore's (1993) original definition for business ecosystems is to emphasise competition between business ecosystems positioned across multiple industries rather than individual companies competing within a single industry. A lone company is not able to compete against inter-organisational structures crossing industry boundaries, like business ecosystems. From a strategy perspective, ecosystem thinking is not a requirement for individual companies but increasingly critical as interdependence between companies increases (Adner, 2017).

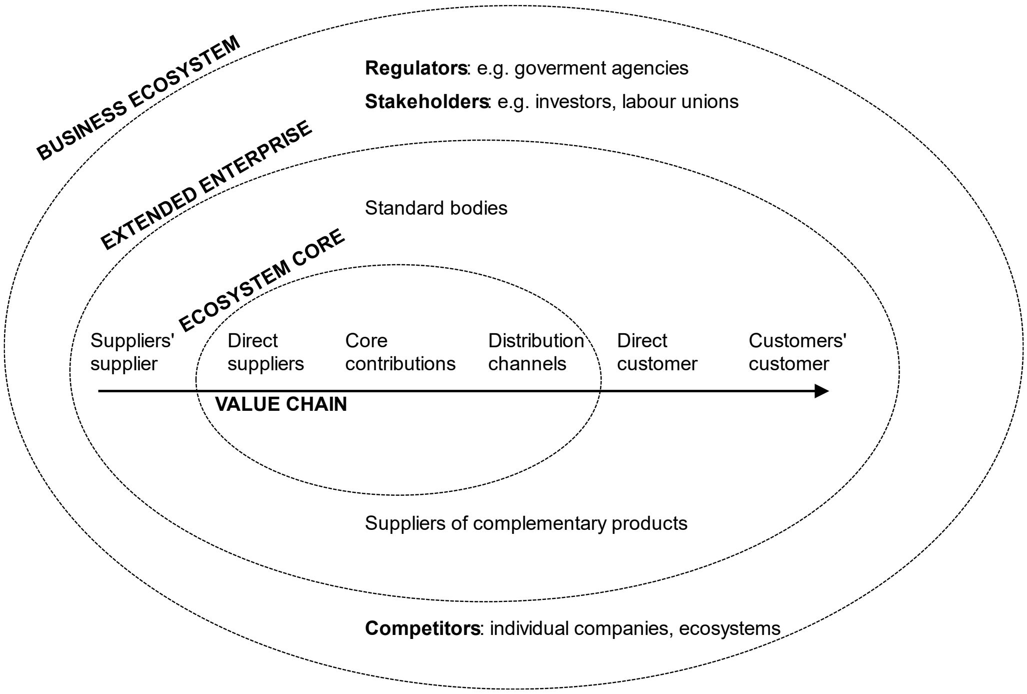


Figure 1.1 Business ecosystem structure with value chain. Adapted from Moore (1996, p. 27).

The evolution of species is another biological metaphor (e.g. evolution theory by Darwin (1859)) closely associated with business ecosystems and ecosystem actors. Business ecosystems co-evolve as ecosystem actors evolve and require evolution from their partners (Peltoniemi & Vuori, 2005) and, from the perspective of an ecosystem actor, they must react to their environment evolving (Peltoniemi, 2006). Central to co-evolution are innovation activities within the ecosystem and its actors (Moore, 1993). Co-evolution is required for the business ecosystem to thrive in their environment (Li, 2009). Moore (1993, p. 76) describes co-evolution as "the complex interplay between competitive and cooperative business strategies", meaning there is a need for finding a balance on evolution within a company and co-evolving as an ecosystem through cooperation.

Competitiveness is required from both the ecosystem and the individual actors within. If individual actors do not co-evolve with their ecosystem, they cannot provide for the evolving ecosystem and will be replaced by competing actors, from within or outside the ecosystem. In the biological context, evolution is a requirement, not a conscious decision by the ecosystem actors. This is the main difference with business ecosystems, where actors consciously make decisions on how to interact with other ecosystem actors (Valkokari, 2015; Moore, 1996). In addition to conscious choice, Peltoniemi (2006) lists three other pre-requisites for co-evolution: scarcity of customers, interconnectedness of organisations, and feedback processes.

Besides business ecosystems, other types of ecosystems formed by organisations are for example innovation ecosystems (Adner & Kapoor, 2010; Ritala & Almpanopoulou, 2017), knowledge ecosystems (Clarysse, et al., 2014), entrepreneurial ecosystems (Spigel, 2017), service ecosystems (Vargo & Lusch, 2016), urban ecosystems (Gómez-Baggethun & Barton, 2013), platform ecosystems (Ceccagnoli, et al., 2012), and industry ecosystems (Wang, et al., 2019). Some of these take a completely different perspective on organising compared to the business ecosystem where value co-creation to customers is essential. For example, an entrepreneurial ecosystem describes the cultural, social and material attributes of an environment (i.e., a country or a location) that enable entrepreneurial activities (Spigel, 2017). An example of an entrepreneurial ecosystem is Silicon Valley. Therefore, in entrepreneurial ecosystems the focus is on the environment of the ecosystem rather than its actors and the activities of the actors. Then again, some ecosystems are rather close to the definition of a business ecosystem and can be thought of as sub- or parallel categories. Innovation ecosystems concentrate on co-innovation within an ecosystem, and therefore collaboration and relationships between ecosystem actors are important (Ritala & Almpanopoulou, 2017). Platform ecosystems consider often digital platforms that enable the operation of most of the ecosystem actors (Ceccagnoli, et al., 2012; Iansiti & Levien, 2004). Examples of such platforms are operating systems, provided by for example Microsoft, Apple, and Google, where thousands of ecosystem actors (see for example Iansiti & Levien (2004)) create software and applications that are only available in the specific platform. The whole business of these ecosystem actors is dependent on the platform provided by the focal actor. The given examples of innovation and platform ecosystems do not conflict with the definition of a business ecosystem but rather can concentrate on different characteristics of ecosystems.

This thesis discusses business ecosystems specifically but does not exclude activities that are more central to other types of ecosystems in organisations. For example, co-innovation can be seen as an important characteristic of innovation ecosystems, but it is also, together with co-creation, central to the co-evolution of ecosystems. Therefore, innovation ecosystems are not necessarily separate entities to business ecosystems but rather parallel, and ecosystem actors can take part in multiple different ecosystems (Valkokari, 2015). Same can be applied to for example service ecosystems, where ecosystem actors create common value through the exchange of services (Vargo & Lusch, 2016). Therefore, a service ecosystem can be a sub-ecosystem for a business ecosystem, where a significant portion of common value is created by the exchange of services, but the overall value would still involve other types of exchanges as well. Those ecosystem types involve characteristics and activities specific to them but do not necessarily contradict with the overall characteristics of co-creation and co-evolution in business ecosystems.

**Mapping collaborative relationships in a business ecosystem**

It is now established that a business ecosystem is an inter-organisational structure characterised by co-evolution led by activities related to value co-creation and co-innovation (Adner, 2006; Rong, et al., 2018). The business ecosystem provides a common value proposition, and each ecosystem actor contributes through value co-creation activities that require collaboration. Ma et al. (2021) studied an electric vehicle home charging ecosystem in Denmark, and as a part of their research they present the ecosystem as a map. In their map, they highlight actors, objects, and different types of relationships between them. Figure 1.2 presents the focal actors of their studied ecosystem to demonstrate the basic principles of the structure of a business ecosystem.

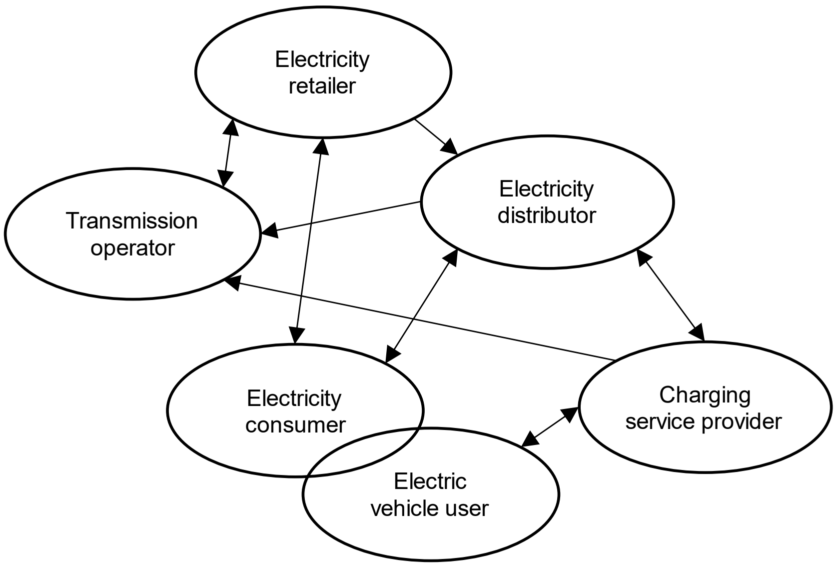


Figure 1.2 Electric vehicle home charging ecosystem (adapted from (Ma, et al., 2021))

Ma et al. (2021) list individual value propositions for each focal actor, but the overall value proposition is to provide home charging as a service for electric vehicles in an electricity market where demand is growing. In short, the ecosystem works so that the electric vehicle user (which is also an electricity consumer in this case) rents a charging device from a service provider and charging-related electricity consumption information goes through the service provider. The electricity consumer also has direct relationships with the electricity retailer and distributor as they consume electricity not related to vehicle charging.

The relationships in the electric vehicle home charging ecosystem can be simple bilateral supplier–buyer ones (e.g. electric vehicle user pays a fee to the charging service to charge their vehicle) or more complex multilateral ones where the decisions are made in collaboration between three or more actors. The relationships drawn as arrows between any two actors in Figure 1.2 are bilateral. However, if you take a group of at least three actors, where the relationships form a loop, you can look at a small part of an ecosystem where decision-making situations involving multiple actors exist. An example of such decision-making can be between the electricity consumer, charging service and electricity distributor to optimise electricity network loads caused by electric vehicle charging. Collaborative decision-making in a multilateral relationship of a business ecosystem is an activity of co-creation accumulating as co-evolution in the long run. In business ecosystems, the focus is on value co-creation towards a common value proposition (Clarysse, et al., 2014).

**Ecosystem thinking required**

As the competitive environments evolve to become more dynamic, companies need to organise their capabilities efficiently to gain competitive advantage, and ecosystem thinking is one solution to this (Teece, 2007). To optimise the benefits that can be gained from business ecosystems, organisations must understand that the collaboration differs from the one in bilateral relationships. More actors being involved brings more uncertainty and risks if not managed accordingly (Li, 2009). Increased interconnectedness and interdependence between ecosystem actors calls for formal controls for the actors to share information, but due to the complexity of business ecosystems, traditional formal controls may not be viable (Peltoniemi, 2005). The organisation of business ecosystems requires new ways for the actors to think about their inter-organisational relations.

The business ecosystem is a structure that is yet to be profoundly studied. Research has concentrated on the roles (Iansiti & Levien, 2004; Wieninger, et al., 2020) and structure of a business ecosystem (Adner, 2017), the lifecycle of a business ecosystem (Moore, 1993; Rong & Shi, 2015) and visualising ecosystems with various tools (Basole & Karla, 2011; Basole, 2014). There is still a lack of understanding on how and why actors within ecosystems behave as they do, and how to manage and improve them. Research has concentrated on understanding what business ecosystems are, but moving further it also needs to be understood how multilateral relationships work and how the ecosystem actors behave in them (Rong, et al., 2018; Jacobides, et al., 2018). Much of the research has been based on case studies where it is recognised that most business ecosystems are managed by their focal actors who control the delivery of the value proposition to the end customer (for example see cases in (Iansiti & Levien, 2004; Basole & Karla, 2011; Rong, et al., 2017)). Often the delivery of the value proposition is through a platform controlled by the focal actor, and therefore the business ecosystem can be clearly defined. Adner (2017) calls these ecosystems-as-affiliate. The other perspective defined by Adner (2017) is ecosystem-as-structure, where the value proposition is focal to the ecosystem rather than to one company. These approaches are not mutually exclusive. As the ecosystem evolves, actors change, the value proposition changes, and what is focal to the ecosystem can change. Co-evolution of the ecosystem also requires the individual actors to evolve and adapt their value creation to accommodate renewed or new business ecosystems. In the worst case, the value an individual company provides within the business ecosystem becomes obsolete and the company is replaced by a different actor.

## 1.2 Scope of the research

The main contribution of this thesis is two Design Science Research (DSR) solution artefacts, EcoGame and Ecosystem Profiler. Each of them has a certain perspective to solving practical problems related to business ecosystems. EcoGame focuses on topics related to ecosystem management and especially collaborative decision-making processes within multilateral relationships. Collaboration within multilateral relationships includes potential benefits but also risks that the ecosystem actors need to be aware of. Ecosystem Profiler makes profiles of ecosystems through patterning. In ecosystem patterning, a key role is played by recognising the relevant actors of an ecosystem, their roles, and the multilateral relationships they form within the ecosystem. The design processes of the two solution artefacts are described in detail in Publications 2 and 3 of this thesis, and the overall DSR process the solution artefacts are a part of, in Chapter 3.1.

As business ecosystems are complex social systems (Peltoniemi & Vuori, 2005), the nature of them can be divided into static and dynamic forms. The static nature can be described by patterning. Ecosystem patterning concentrates on three of the four elements (see (Adner, 2017)) ecosystems are constructed of: actors, their positions in the ecosystem, and links between them. The fourth element, the activities of the ecosystem actors, is part of the dynamic nature of business ecosystems and highlighted in ecosystem management. Ecosystem patterning is used to interpret the ecosystem actors and linkages between them and present them in multiple forms, e.g. visually and in financial terms (Publication 2). The goal of patterning is to create a comprehensive presentation of the static nature of a business ecosystem by displaying business ecosystem actors and their roles and relationships within the ecosystem.

Due to being a presentation of the static nature, ecosystem patterning considers the business ecosystem in a single point in time and thus cannot comprehensively contribute to the understanding of the dynamic nature of evolving ecosystems. Ecosystem patterning can be used to capture parts of the dynamic nature through a series of observations of the static nature as the ecosystem evolves (Iyer & Basole, 2016). However, understanding why changes occur, the dynamic nature is interpreted through ecosystem management, which consists of managing the dynamic co-creation activities (Adner, 2017; Valkokari, 2015; Altman, 2016) within the business ecosystem, which lead to co-evolution over time. Different levels of ecosystem management are required at different points of the ecosystems' evolution but, overall, co-evolution requires collaboration between actors

(Moore, 1993; Moore, 2006). This increased interdependency between actors compared to other inter-organisational structures also involves potential benefits and risks specific to business ecosystems. If the ecosystem actors are not familiar with the structure of their ecosystem, they will avoid multilateral collaboration to not see any of the risks realise.

Collaborative decision-making processes within the ecosystem are central to co-creation, which leads to the delivery of the ecosystem's value proposition. Most decision processes involve multiple actors in a multilateral setting and can be located in different parts of the ecosystem. The decision processes can be centred on one or few focal actors and their relationships within the business ecosystem, leading to ecosystem management being centred on the same focal actors. This occurs especially in platform ecosystems where the focal actor manages their ecosystem through a platform they provide (Ceccagnoli, et al., 2012; Iansiti & Levien, 2004), but can also occur in business ecosystems with strong or dominating focal actors.

To understand and present both the static and dynamic natures of business ecosystems, new solutions are required (Jacobides, et al., 2018). A solution is by definition "an action or process of solving a problem, and specifically: a set of values of the variables that satisfies an equation" (Merriam-Webster, 2021). A solution is created to answer a problem, and the quality or degree of answering the problem is secondary in the context of complex social systems due to their unpredictability (van Aken, 2014). Jacobides et al., (2018) and Rong et al., (2018) both call for creating more understanding on the dynamics of business ecosystems, including the topics of management and collaboration. Solutions discussed in this thesis relate to games, mapping and other solutions including processes, frameworks, and methods discussed in literature. The solutions created and presented in this thesis to answer the call of creating more understanding are more specific (i.e., EcoGame – a serious game for ecosystem management through collaborative decision-making in multilateral relationships; and Ecosystem Profiler – patterning an ecosystem to create a static view to the structure of it). Especially their joint use aims to combine the knowledge gained from previous research and solutions for business ecosystems to create new knowledge in the areas that are not yet profoundly studied. The overall scope of this thesis is presented in Figure 1.3.

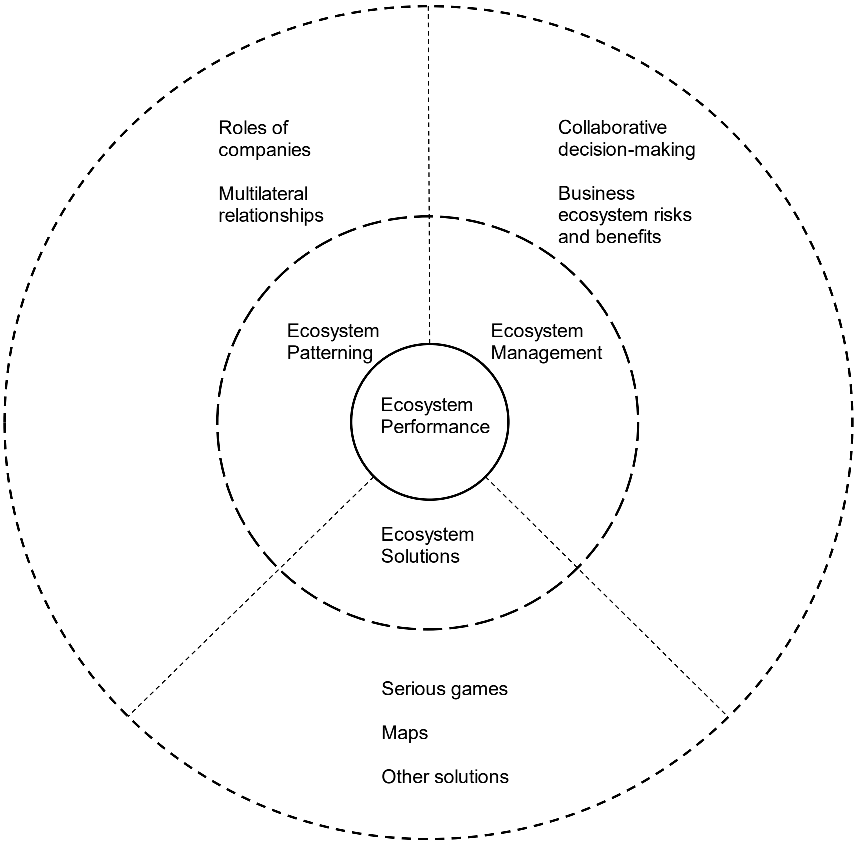


Figure 1.3 The overall scope of this thesis.

In the centre of the scope of this thesis is the practical motivation of companies to organise as business ecosystems or other collaborative structures – to improve individual and joint performance. However, metrics to measure ecosystem performance do not exist yet, and measuring is difficult overall (Graça & Camarinha-Matos, 2017; Ritala & Almpanopoulou, 2017). Through a combination of ecosystem patterning and management with EcoGame and Ecosystem Profiler, this thesis proposes to improve the performance of the participating ecosystems and create understanding on how to measure them. This requires the DSR solution artefacts to be validated to contribute in such level of formal theory (Holmström, et al., 2009). Therefore, the current contributions from the two solutions are located in the layer around ecosystem performance. On the outermost layer of Figure 1.3 are located the more specific ecosystem elements. The dashed lines show that the position of the elements are not fixed, and more context-specific elements would be located in the following layers not displayed here.

## 1.3 Research purpose and questions

The concept of a business ecosystem and ecosystems of organisations in general have attracted interest among research within inter-organisational relations and practitioners who have observed the growing amount of interconnectedness (Peltoniemi & Vuori, 2005). Research on business ecosystems has concentrated on the static nature of ecosystems, who the actors in them are, and what kind of relationships exist between the actors (Rong, et al., 2018). Various static presentations of business ecosystems exist in different forms of visualisations (Basole, 2014), but solutions for understanding and presenting the dynamic nature of business ecosystems are fewer (Jacobides, et al., 2018). For example, Battistella et al. (2013) presented a methodology to study both the static and dynamic nature of a business ecosystem, but it requires a lot of resources to use. Most of the different solutions are conceptual tools that require the user to provide the data. In the context of this thesis, solutions that are ready to be used by the ecosystem actors to gain new insights into both static and dynamic nature of the business ecosystem are of interest.

Much of previous research studies cases where the focal actor of the ecosystem is evident, and the ecosystems value proposition is synonymous to the activities of the focal actor (Jacobides, et al., 2006; Rong & Shi, 2015). This kind of approach is understandable as it offers a way to present the dynamic nature of the ecosystem clearly in a manner where the static nature is still comprehensible. Tools that create ecosystem visualisations and maps are good examples of solutions for the static nature (Basole, et al., 2016; Iyer & Basole, 2016) but they often do not consider the dynamic nature. The ecosystem actors give necessary inputs and receive a visual presentation of their ecosystem that they can use for analysis. This approach is able to show the connections between actors and sub-systems within the ecosystem through the locations of the ecosystem actors.

Showing only the complex static nature undermines the dynamic nature that involves activities related to the main characteristics of business ecosystems, co-evolution and co-creation. Simulation within games can be used to study the dynamic nature of complex business ecosystems (Bekebrede & Mayer, 2006; Lukosch, et al., 2018). For example, the behaviour of ecosystem actors in a multilateral decision-making process is dynamic information that is difficult to observe without simulation (Klabbers, 2018). A game as a solution should also require a low amount of resources from the ecosystem actors but provide a lot of information on what it is set to study.

A combination of different solutions is useful as different situations in business ecosystems might require different types of information for analysis (Rong, et al., 2018). It is crucial to be able to both describe the static nature of a business ecosystem where the actors and their locations and connections between the actors are relevant, and to make sense of the dynamic nature, where the activities related to co-creation and co-innovation are important. Combining the static and dynamic nature creates understanding on how business ecosystems evolve over time.

Due to the complexity of business ecosystems, capturing both the static and dynamic nature with a single solution artefact is not required. Instead, the purpose of my research is to create two solutions that are separately and together able to build understanding on the nature of business ecosystems, both for research and management within the ecosystem. Ultimately leading to understanding how to improve and measure the performance of business ecosystems. The solutions are created as DSR artefacts where rigorous utilisation of existing knowledge base enables the creation of artefacts relevant to the target environment. The two solutions created within the current DSR process use existing solutions proven in other contexts as a part of their knowledge bases. This thesis is set to answer the following research questions:

RQ1. Which solutions can be used in studying business ecosystem management?

RQ2. How are the solutions created as DSR artefacts?

RQ3. What is the contribution of the solutions to knowledge base, consisting of ecosystem patterning, management, solutions, and performance?

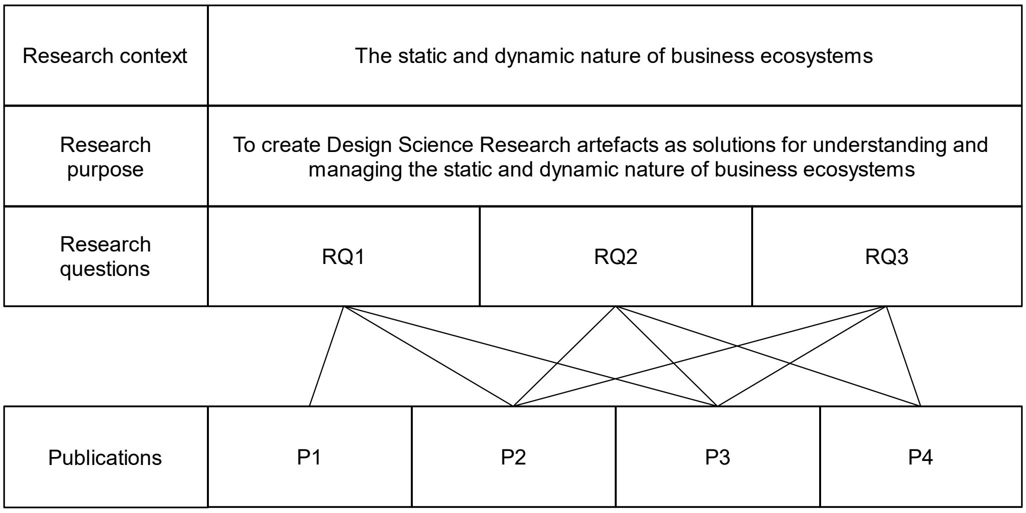


Figure 1.4 Research context and purpose, and links between research questions and publications.

Presented in Figure 1.4 are the research context and purpose, as well as the research questions and how they are connected to the publications included in this thesis. For RQ1, P1 reviews the literature on serious games used for training in organisations, and P2 and P3 present their field of knowledge as part of their own DSR processes. As mentioned, P2 and P3 discuss DSR processes specific to the solutions discussed in each publication and as such answer RQ2. P4 in part is a part of a knowledge base for the DSR process in P3 and thus is relevant for RQ2. RQ3 is answered by P2, P3 and P4 as they all discuss implications towards either or both the static and dynamic nature of business ecosystems.

## 1.4 Structure of the thesis

This thesis is structured in two parts. The first part consists of five chapters: Introduction, Theoretical background, Research design, Review of the results, and Conclusions. The second part includes the four publications this thesis is based on. The purpose of the first part is to describe the overall research process of the thesis and connect the publications in the second part. Introduction includes the background and motivation, scope, and purpose of the thesis. Theoretical background presents the previous literature relevant to this thesis, and Research design describes how the research presented in the thesis has been conducted. Review of the results goes through the results of each publication separately and discusses the results in the context of the overall thesis providing answers to the set research questions. Conclusions presents the contribution and evaluation of the thesis, limitations of the research, and topics of future research.

# 2 Theoretical background

## 2.1 Business ecosystem patterning

Business ecosystem is a dynamic structure which forms naturally from organisations collaborating closely (Peltoniemi & Vuori, 2005; Moore, 1998). Even though the formation is natural like in ecology, business ecosystem actors do not form relationships without consideration (Valkokari, 2015; Moore, 1996). However, the increasing size of a business ecosystem does make its boundaries unclear and difficult to manage (Gulati, et al., 2012). Each ecosystem is unique, and actors can have roles in multiple partially overlapping ecosystems (Valkokari, 2015; Bosch-Sijtsema & Bosch, 2015). The view of the ecosystem should not be limited to a platform but instead structured based on relationships between the actors (Weber & Hine, 2015).

Ecosystems are constructed of four elements: activities, actors, positions, and links (Adner, 2017). Business ecosystem patterning mainly considers actors, positions, and links, whereas business ecosystem management concentrates on the activities. At the centre of a business ecosystem is the core, where actors focal to the delivery of the value proposition are located (Moore, 1996; Iansiti & Levien, 2004). Actors who are indirectly contributing to the value creation are located in the outer layers. These actors can include for example competitors, regulators, and investors. The effect of these companies is indirect but can be crucial for the competitiveness of the business ecosystem (Heikkilä & Kuivaniemi, 2012; Moore, 1996). Koenig (2012) criticises Moore and some other business ecosystem literature of only including the core of an ecosystem and relationships around the focal actor in the presented cases. However, the original definition by Moore and its adaptations involve peripheral actors that are relevant to the ecosystem while not necessarily directly connected to the focal actor (Koenig, 2012). If the focus is only on the focal actor and their links and activities, one could argue that the structure in question is a cluster (Porter, 1990), business network (Halinen & Törnroos, 2005) or value network (Allee, 2002). Peltoniemi (2005, pp. 61-63) compares these structures and discusses their differences.

In literature, business ecosystems are discussed from two perspectives: one where the ecosystem is characterised and formed around a focal actor, a core company, (Moore, 1993; 1996) and the other where central to the formation of an ecosystem is the value the business ecosystem provides (Adner, 2017). Adner (2017) calls these perspectives ecosystem-as-affiliation and ecosystem-as-structure, where the latter extends the original view of Moore and takes it into the opposite direction considering strategy construction. The approaches are not mutually exclusive but can rather be both applied in some cases to one business ecosystem (Adner, 2017). For example, a business ecosystem formed around a focal actor evolves and the value proposition it provides can change so that the once focal actor loses its role. This thesis considers both perspectives relevant. When one begins to study a business ecosystem, it might not be evident who the focal actor is or what the value proposition delivered to customers is.

### Roles of companies

Moore’s view (Moore, 1993; 1996) divided the roles of companies in a business ecosystem to leaders, whose purpose is to promote new ideas and maintain the evolution of the ecosystem, and niche players whose role is to create value towards the common value proposition. Iansiti and Levien (2004) called the roles of ecosystem actors as keystones, dominators, and niche players. A role within an ecosystem is used to describe the activities an actor conducts (Dedehayir, et al., 2018), and the role also reflects the actor’s status in the ecosystem and potentially their future goals (Iansiti & Levien, 2004).

Keystones can be understood as similar to the leaders by Moore, as their purpose is to create and share value within their ecosystem through providing value creation means for niche players (Iansiti & Levien, 2004; Dedehayir, et al., 2018). The keystones have the greatest impact to the overall wellbeing of the ecosystem and its actors, even though they are the smallest in number (Clarysse, et al., 2014; Iansiti & Levien, 2004; Moore, 1993; Mäkinen & Dedehayir, 2012). If a keystone is removed from their ecosystem, the whole ecosystem can collapse and thus cause damage to individual ecosystem actors that have varying levels of dependence towards the ecosystem. Dominators are large actors that, in addition to collaboration, compete within the ecosystem (Mäkinen & Dedehayir, 2012). They aim to take over functions from other actors within the ecosystem, and therefore reduce the diversity within the ecosystem. Reduced diversity negatively affects the agility of the ecosystem when facing changes. Niche players are the largest in number and have focused capabilities (Iansiti & Levien, 2004). Being a niche player does not necessarily mean that the actor is small in size but rather that they play a niche role in the specific business ecosystem. After joining a business ecosystem, niche players extend the ecosystem by expanding their connections with the available collaborative opportunities (Overholm, 2015).

Dedehayir et al. (2018) reviewed literature to recognise roles in the context of innovation ecosystem birth. The lifecycle of an ecosystem is discussed in relation to business ecosystem management in Chapter 2.2. The synthesis of roles by Dedehayir et al. (2018) link ecosystem leaders and dominators together into the role group of ‘Leadership’. Other role groups are ‘Direct Value Creation’, ‘Value Support’, and ‘Entrepreneurial Ecosystem’. These role groups include ecosystem actors that Moore (1993) and Iansiti and Levien (2004) more simply categorise as niche players. In business ecosystems, these can include for example customers (Direct Value Creation), research organisations (Value Support), and investors and regulators (Entrepreneurial Ecosystem). In a dynamic structure like business ecosystems, the role an actor takes can vary as the ecosystem evolves (Iansiti & Levien, 2004). Very detailed breakdowns of roles (e.g., (Wieninger, et al., 2020)) can be useful for the static nature of business ecosystems, but the goal of ecosystem patterning is not only to capture the static nature but together with ecosystem management create understanding of the dynamic nature. Therefore, in the context of this thesis it is crucial to be able to recognise the keystones (called focal actors), while other actors can be categorised as niche players that are further defined by the activities they conduct within the ecosystem at different stages of its evolution.

### Multilateral relationships

Business ecosystems consist of multilateral relationships where the relationships between companies cannot be broken down to bilateral ones and are not completely hierarchically controlled (Jacobides, et al., 2018). Companies participating in multilateral relationships are often more dependent on each other compared to bilateral relationships, for example in supply chains (Adner, 2017). Multilateral relations is a concept most commonly used to describe international relations in international organisations such as United Nations, or other agreements involving multiple states. The purpose of multilateral relations is to reduce uncertainty and promote openness through collective agreements instead of series of bilateral diplomacy (Ruggie, 1992). The purpose of multilateral relationships in business ecosystems is similar – to move forward from bilateral agreements towards more open and predictable operations. From the perspective of a focal actor, a multilateral relationship may increase their uncertainty and reduce control, but the whole ecosystem can benefit as the niche players can plan their operations within the ecosystem better.

Ecological relationships within ecosystems can be described in three categories: symbiotic, predatory, and competitive relationships (Lang & Benbow, 2013). Moore (1993) described that the actors of business ecosystems can have both collaborative and competitive relationships, and as a wider concept this can be called co-opetition (Mäkinen & Dedehayir, 2012). Predatory behaviour is expected from those ecosystem actors who act aggressively to maintain their position within the ecosystem, often at the expense of other ecosystem actors. Competitive relationships do not need to be predatory but rather together with collaborative relationships drive co-evolution of the ecosystem forward.

Supply and value chains are inter-organisational structures that consist of bilateral relationships. They are also a part of the ecosystem structure presented by Moore (1996). Therefore, it is natural that the relationships of business ecosystems are derived from and compared with bilateral relationships. The relationships in supply chains are bilateral between suppliers and customers by nature, and therefore simple compared to multilateral relationships in business ecosystems. The bilateral relationships can be controlled and monitored formally with contracts and agreements. A closed multi-tier supply chain where all actors are linked (see (Mena, et al., 2013)) resembles a multilateral relationship, but the links between actors can still be broken down to bilateral ones. In business ecosystems, the organisations do not necessarily act just as suppliers and customers, but rather can create indirect value through for example research, innovation, financing, and competition. Figure 2.1 illustrates a multilateral relationship from the ecosystem mapped by Ma et al., (2021) previously discussed in Chapter 1.1. Considering the relationship loop of an electricity consumer, electricity distributor, and charging service, where all actors are linked together, they form a collaborative, competitive or co-opetitive multilateral relationship where collaborative decision-making affects all involved actors. In this relationship, the flows and interactions between actors are versatile: goods, monetary, data, information, and intangible (Ma, et al., 2021). Therefore, the dynamics of the relationship are more complex than in one where the relationship is based on transactions between two actors.

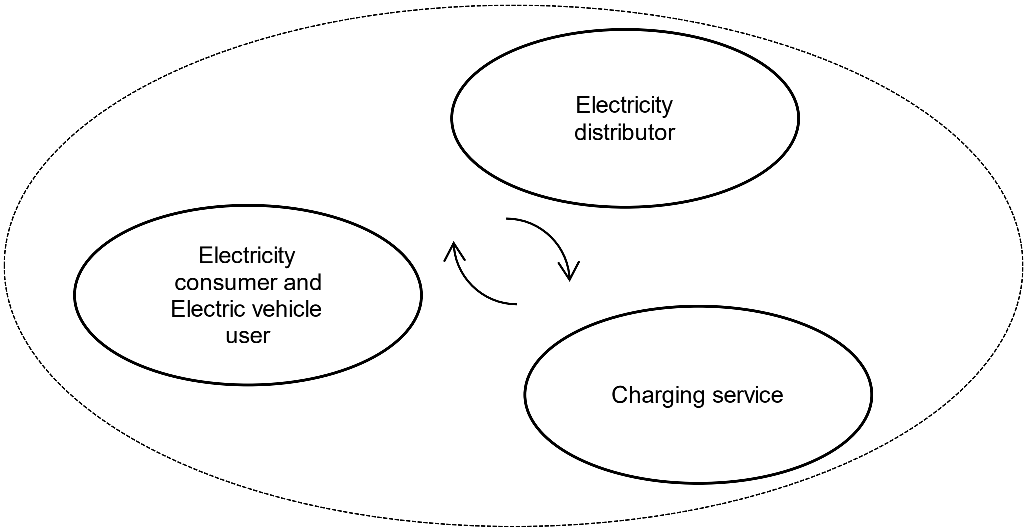


Figure 2.1 A multilateral relationship within the electric vehicle home charging ecosystem (Ma, et al., 2021)

The multilateral relationships within a business ecosystem, where most of the decisions impacting the value proposition are made, are located close to the core of the business ecosystem. The focal actors in the core are much more connected than the majority of ecosystem actors (Iansiti & Levien, 2002). The less an actor provides for the value proposition, the less relationships they form within the business ecosystem. To draw conclusions on the dynamic nature of the whole business ecosystem, one only needs to look at the activities within multilateral relationships located in the core (Iansiti & Levien, 2004).

## 2.2 Management of business ecosystems

Management in business ecosystems can be considered in two levels: management of the overall co-evolution of the ecosystem (e.g., (Li, 2009)), and management of ecosystem relationships and co-creation activities by the ecosystem actors on an individual level (Autio & Thomas, 2014). Overall, management of a business ecosystem is managing the interdependencies and activities of ecosystem actors (Adner, 2017; Valkokari, 2015; Altman, 2016). A co-evolving business ecosystem is characterised by a certain level of openness and alignment between the actors (Moore, 2006). An ecosystem actor having a dedicated resource for managing their participation in the business ecosystem leads to a higher level of collaboration in their multilateral relationships (Kapoor, 2014). Higher level of collaboration then allows opportunities for improved value co-creation by the ecosystem (Davidson, et al., 2018) but also brings challenges to the ecosystem actors (Dedehayir, et al., 2018).

The evolutionary stages of a business ecosystem and its actors also affect management and what is required from it. Moore (1993; 1996) presented the lifecycle of a business ecosystem in four phases: birth (or pioneering), expansion, leadership (or authority), and self-renewal or death. Rong and Shi (2015) ties their presentation of a five-phase business ecosystem lifecycle to market maturity, but the contents of the phases are similar to Moore's, where the focus is on a focal actor instead of market or product. The lifecycle begins from birth, where a new value proposition is defined, and ends with renewal or death, where the ecosystem either succeeds or fails in innovation that would put them back in the birth phase. The maturity of an ecosystem actor defines on an individual level the resources they have available for managing ecosystem participation and their vulnerability to competitive or predatory behaviour within the ecosystem (Altman, 2016).

Many of the studies presenting cases of business ecosystems consider the ecosystem from the perspective of the focal actor (e.g. Wal-Mart example in (Iansiti & Levien, 2004)). This perspective puts the focus of ecosystem management towards the focal actor managing the overall co-evolution of its ecosystem. This is not necessarily an issue but it can be a symptom of a focal actor dominating their ecosystem. A business ecosystem with multiple focal actors that does not concentrate value co-creation activities to just one or the few instead requires management more through collaborative decision-making.

**Collaborative decision-making**

Value co-creation in a business ecosystem creates a need for companies to collaborate, and collaboration in multilateral relationships concretises as decision-making processes between multiple actors (Jacobides, et al., 2018). Collaboration between actors in a business ecosystem is not meant to limit competition, but instead they both aid in the co-evolution of the ecosystem and its actors and support innovation (Moore, 1993; Peltoniemi, 2005). Engaging in collaboration is important for individual actors. As the ecosystem evolves, it will constantly change, and actors are changed to ones who can provide more value and improve the value proposition an ecosystem delivers (Moore, 1993).

The decisions made in the business ecosystem affect the co-evolution of the ecosystem and create a basis for future decisions (Valkokari, 2015). Therefore, information and knowledge sharing for decision-making between ecosystem actors have great impact on the whole ecosystem. In inter-organisational relationships, there are formal controls such as contracts to govern information sharing, but in increasingly complex multilateral settings the role of informal controls, such as trust and commitment between the individual decision-makers, play a larger role (Wulf & Butel, 2017). For business ecosystems, it can be more beneficial to develop interpersonal ties between ecosystem actors to facilitate information sharing required in decision-making processes. The coordination of these relationships is based on personal or professional trust and commitment (Machado & Burns, 1998).

One of the recognised differences between ecological and business ecosystems is that business ecosystem actors make conscious decisions (Peltoniemi, 2005; Ritala & Almpanopoulou, 2017). Rational decision-making assumes that all information required to make a decision is available (Citroen, 2011). In complex dynamic collaborative relationships, it is unlikely that decision-making is always rational as the ecosystem actors are reluctant to share individually sensitive information with their collaborators. Actors are comfortable with sharing technical knowledge for collaborative decision-making (Feller, et al., 2009; Li, et al., 2012) but not detailed cost or profitability information (Kajüter & Kulmala, 2005; Windolph & Möller, 2012; Sinkkonen, et al., 2013). However, rationality and consciousness are different concepts. The complexity of strategic decisions can lead to long decision processes as the ecosystem actors attempt to reach a sufficient level of rationality by gathering more information. The long processes also contribute to the consciousness of decision-making (Abadie & Waroquier, 2019). Improving information sharing can lead to shorter decision processes and unconscious decision-making in business ecosystems or it could be irrelevant as the ecosystem actors would always prolong the decision process to gather more information to make a rational, conscious decision.

**Business ecosystem benefits and risks**

By participating in collaborative inter-organisational structures, companies can improve their performance and reduce costs (Ramanathan & Gunasekaran, 2014; Audy, et al., 2010). In a business ecosystem, actors work towards a common goal through co-creation and deliver value to end customers within their ecosystem. Through co-evolution the ecosystem and its actors stay innovative and agile to survive changes in the market and in the value they provide (Autio & Thomas, 2014; Iansiti & Levien, 2004; Moore, 1996). Each ecosystem actor participates in the delivery of the value proposition and therefore gains benefits from it. How the benefits and created value are shared depends on the strategies of the focal actors of the business ecosystem (Zhang & Liang, 2011). Due to specific value provided by each actor, there are no overlapping roles, and operation can be more efficient than in for example supply chains (Inoue & Nagayama, 2011). Every actor has a role that makes them an essential part of the ecosystem, and therefore the whole ecosystem is interdependent on each other (Chen, et al., 2014). A sign of a healthy business ecosystem is when it is able to renew itself each time it reaches the end of its lifecycle. This requires co-evolution and changes in their value proposition and ecosystem structure to be able to lower their costs and reach new markets (Lee, et al., 2020). Williamson and De Meyer (2012, pp. 33-44) discuss six keys to gain advantage from ecosystem participation: pinpointing the added value, structuring differentiated partner roles, stimulating complementary partner investments, reducing transaction costs, enabling flexibility and co-learning, and engineering value capture mechanisms.

Increased interdependency between ecosystem actors also increases the perceived risks for individual actors (Lo Nigro & Abbate, 2011; Adner, 2006) as interdependence requires coordination (Jacobides, et al., 2018) which can be difficult in business ecosystems. Besides interdependency, the other two categories of risks related to co-innovation within an ecosystem are related to initiatives and integration – how co-innovation activities are managed, and how innovations are integrated within the ecosystem (Adner, 2006; Li & Garnsey, 2014). Information sharing is a key element to reaching ecosystem benefits, but it also causes uncertainty on how the information is used by the other ecosystem actors (Hallikas, et al., 2004). In bilateral relationships the dynamic is easier and can be based on formal control methods, for example contracts. In business ecosystems, due to the complexity of the relationships, risk management is based on informal control methods. As a summary to perceived risks, Fawcett at al. (2007) and Audy et al. (2010) observe five barriers to information sharing: cost and complexity of technologies, incompatibility of systems, connectivity issues, lack of willingness to share, and information security and confidentiality.

Smith (2013, p. 31) lists risks associated with different types of business ecosystems when entering a business ecosystem as a new actor. Risks involved with the increased overall complexity of organising and distributing activities between actors is present in all types of business ecosystems (Adner, 2006; Iansiti & Levien, 2004). Also, risks related to co-opetition (see Moore (1993, p. 77)) exist regardless of the category of the business ecosystem. Other risks listed by Smith (2013, p. 31) are related to control, intellectual property rights, interdependence, and business models. Smith and Moore describe risks and challenges from different perspectives – a niche player entering a business ecosystem, versus a focal actor leading an ecosystem. The realisation of both the benefits and risks depends largely on the focal actors of a business ecosystem (Iansiti & Levien, 2004). Niche players entering a business ecosystem need to be aware of the static and dynamic nature of it, while focal actors must provide a healthy ecosystem or they will see niche players moving away from their ecosystem (Smith, 2013; Iansiti & Levien, 2004). Also, a niche player can act as a bottleneck in an unhealthy ecosystem, preventing the realisation of benefits and creating competitive disadvantage (Mäkinen & Dedehayir, 2012).

## 2.3 Solutions for business ecosystems

Previous literature has noted that solutions for studying the dynamics of business ecosystems is lacking (Jacobides, et al., 2018). Research has concentrated on solutions that present ecosystems in a static form (Basole, et al., 2016; Iyer & Basole, 2016), but that kind of presentation lacks information on the essential topics of co-creation activities and co-evolution of ecosystem actors. The static presentations are necessary to display the complex social structure of a business ecosystem, but as important are solutions that aim at creating understanding on and improvements in the dynamic nature of business ecosystems (Rong, et al., 2018; Jacobides, et al., 2018).

**Serious games**

Games are traditionally known to be used for entertainment, but games and gamified applications have also been used for educational purposes and training in organisations (Garris, et al., 2002). Games can incorporate simulations of processes which are used for intra-organisational training but also for studying complex social systems like business ecosystems (Bekebrede & Mayer, 2006). In such cases, simulation within games can be used for example to study the behaviour of and interactions between actors, and the results from the game can be related to reality together with other instruments (Lukosch, et al., 2018). Serious game is an approach to combine the entertainment and training purposes of games (Zyda, 2005; Dörner, et al., 2016). The entertainment aspect of serious games has the purpose of immersing the players and ensuring that the simulated processes presented in a game yield results that are relevant for research. Collaborative decision-making processes in business ecosystems can occur scarcely, and simulating them in a serious game can provide a way for the ecosystem actors to compare alternative decisions and improve their processes (Abt, 1970).

Serious games are used more for training in intra-organisational decision-making processes than in inter-organisational (Publication 1). Revisiting the search criteria (see first search string in Table 2.1) used in the systematic literature review of P1, it can be noted that the number of papers published about serious games for training in decision-making has increased. P1 reported 197 search results (search conducted in January 2018), and it currently (search conducted in July 2021) returns 372 results, showing an increase of 89%. Table 2.1 shows the evolution of different search results relevant for this thesis from the time of P1 compared to today. The searches for P1 were conducted in January 2018, and therefore some of the results now found for 2017 were not yet available in the search of P1.

Table 2.1 Searches conducted relevant to P1 and the whole thesis.

| **Search string** | **-2017** | **2018-** | **Increase** |
|---|---|---|---|
| TITLE-ABS-KEY (((”serious game” AND ”decision making”) AND NOT (”education” AND NOT ”training”))) | 205 | 167 | 81% |
| TITLE-ABS-KEY ((”serious game” AND ”decision making” AND “management”) AND NOT (”education” AND NOT “training”)) | 69 | 59 | 86% |
| TITLE-ABS-KEY ((”serious game” AND ”decision making”) AND (”inter-organisational” OR ”network” OR ”ecosystem”)) | 16 | 23 | 144% |

The last search string in Table 2.1 refers to the purpose of P1. Searching for papers describing the use of serious games for collaborative decision-making in an ecosystem or similar setting yielded few results. None of the 16 papers from before 2017 fit the inclusion criteria of P1. Therefore, P1 extended the scope to search for papers describing the use of serious games in training in decision-making in general. Conducting the search now yielded 39 results of which 23 were published since 2018. Going through the papers now reveals that at least five papers (Roukouni, et al., 2020; Gissi & Garramone, 2018; Jean, et al., 2018; Speelman, et al., 2014; Scharpff, et al., 2021) published since 2018 are relevant to the serious game solution presented in this work. Especially the work of

Roukouni et al. (2020) perfectly fits the criteria of P1 and considers the complex social system of an innovation ecosystem.

**Ecosystem maps**

Ecosystem mapping refers to visualising the structure of an ecosystem and using visual methods (e.g. positions, shapes, and sizes) to express information on its parts (Iyer, et al., 2006). Here the organisational context of ecosystems differs quite a bit from the maps in ecology or geography where the maps often describe physical structures. Maps are static visual presentations, and therefore the dynamic nature of a business ecosystem can only be captured to some extent within a map (Iyer & Basole, 2016; Iansiti & Levien, 2004). There are multiple goals of mapping business ecosystems. For example, to recognise the focal actors, multilateral relationships and relationship loops, or to update a previous map to recognise changes (Basole, et al., 2015; Iyer & Basole, 2016). By updating and comparing changes between maps, interpretations into the dynamic nature of a business ecosystem can be made. The overall purpose of a business ecosystem map is to make it easier to interpret the structure (Basole, et al., 2015) and allow both researchers and practitioners to utilise it (Basole, et al., 2016).

Due to the complexity and scope of business ecosystems, the amount of data available for mapping is vast. Therefore, it is important to set boundaries for the information to be presented with the map (Conway, 2014). The amount of data included in the map can change the way it is interpreted (Basole, et al., 2015). For example, including just the focal actors and connections between them can help in understanding the key relationships of a business ecosystem but omit important connections that are not evident. On the other hand, attempting to include all actors involved in the business ecosystem can help reveal numerous connections that are not evident to all stakeholders, but the nature of relationships cannot be described. See for example Uusikartano et al. (2021, p. 7) for an ecosystem map highlighting the key relationships of a focal actor and Faber et al. (2018, p. 92) presenting multiple techniques to map a large amount of ecosystem actors and their connections.

**Other solutions**

Other solutions for business ecosystems relevant in the context of this thesis are various types of frameworks, guides, methods, processes, and concepts. They require the user to create the information to be interpreted, and therefore might not provide new insight for the user (Adner, 2006). However, they can be of use through for example promoting the context of the tool and integration of ecosystem actors (Bertassini, et al., 2021). Battistella et al. (2013) propose and test a methodology to study the structure of a business ecosystem from both static and dynamic perspectives. They present the focal actors of the ecosystem and their relationships and then analyse and forecast the future of the market and the actors to understand the dynamic nature of the business ecosystem. Their methodology requires a lot of different resources to achieve its goals while not necessarily involving the ecosystem actors in the process.

Even if the other solutions are not able to provide new insights, they can be used as a starting point in studying or managing business ecosystems. For example, Waßenhoven et al. (2021) propose a framework to detect industries in emerging business ecosystems. Humbeck et al. (2020) have combined different characteristics of business ecosystems into a business ecosystem management canvas for the actors to reflect on them. Other solutions will increase in variety as business ecosystems are studied further. For example, mathematical models are scarce even though other inter-organisational structures (e.g., supply chains (Shi, et al., 2014; Yao, et al., 2008)) have been modelled.

## 2.4 Business ecosystem performance

Performance is measured and used for strategic management in individual organisations. The metrics or indicators used for performance are linked with corporate strategy (Kaplan & Norton, 1996). For business ecosystems, the ecosystem strategy often reflects the strategies of the focal actors. However, the performance of business ecosystems is linked to the overall health of the ecosystem and its actors (Iansiti & Levien, 2004; Kim, et al., 2010). Therefore, business ecosystem performance cannot only consider the focal actors but instead the ecosystem as a whole (Adner & Kapoor, 2010; Mäkinen & Dedehayir, 2012). The complexity of a business ecosystem creates costs related to the coordination of relationships (Handley & Benton Jr., 2013) and can thus display lower performance from a cost perspective in comparison to simpler structures. Therefore, it is important to also consider the monetary value of benefits gained by engaging in business ecosystems and assess comparative performances through cost-benefit analysis.

Performance measurement of systems involving multilateral sets of partners is difficult in general (Ritala & Almpanopoulou, 2017). Graça and Camarinha-Matos (2017) recognise that there are no suitable performance metrics or indicators established specifically for business ecosystems, and thus they review performance metrics used for different collaborative network structures such as supply chains and value networks. The metrics used for other collaborative structures can in part be used for business ecosystems, and Graça and Camarinha-Matos highlight examples from value networks (see (Allee, et al., 2015)) as the most suitable ones. In value network analysis, the focus is on the complex dynamic exchanges between actors, involving both tangible and intangible value (Allee, et al., 2015).

Ecosystem performance can be divided into internal and external factors (Xie, et al., 2019). Internal factors mean the performance related to ecosystem actors and their relationships while external consider the environment the ecosystem operates in. In the case of a business ecosystem, competition has a key role and therefore external factors are important. The association of value network performance indicators to business ecosystems takes well into account the co-creation activities and related internal dynamics of ecosystem actors. However, external factors are not considered. As noted by Graça and Camarinha-Matos (2017), further work is required to compose performance metrics and indicators for business ecosystems. Only after that, existing solutions (e.g.

The Balanced Scorecard (Kaplan & Norton, 1996)) and new solutions for performance measurement and management in business ecosystems can be created.

# 3 Research design

## 3.1 Research approach

Design Science Research (DSR) originates from the need to design artefacts that are used to solve problems existing around us and change the existing situation into a preferred one (Simon, 1996). This need can be called design-in-the-large and the actual construction of artefacts design-in-the-small (Klabbers, 2003b). Design-in-the-large provides us context to understand the systems we design the artefacts for. Business ecosystems and multilateral relationships within them are complex social systems involving multiple actors, multiple individuals and various parameters affecting the behaviour of actors in a relationship. In such complex social systems, the behaviour of the system is difficult to predict (Klabbers, 2003b), which in turn makes the designing of the artefacts for the system complicated. The end goal of DSR is to be able to generalise the artefact, but as behaviour is difficult to predict, generalising the outcomes of a DSR artefact requires deep understanding on the context (van Aken, 2004). Through generalisation, knowledge is created that can be used in further design processes (van Aken, 2004; Kasanen, et al., 1991). Opposite to complex social systems are material systems that have predictable behaviour, and artefacts for such systems are easier to generalise (van Aken, 2014). The artefacts designed for social systems aim to enhance the situation described in the problem that initiated the design process (Klabbers, 2003a). The users of the artefacts must be able to use them as designed so that the results gained are relevant in the DSR process (van Aken, et al., 2016).

**Philosophical positioning**

DSR as a research approach does not limit the usage of research methods (Iivari, 2007). Neither does DSR stem from a single research paradigm, but instead design science can be seen as its own research paradigm (van Aken, 2004). Van Aken (2004) compares design science as a paradigm to the explanatory research paradigm, which aims at creating understanding on the aim of the research. Design science does not only aim at understanding but developing knowledge to create solutions for further problems. Design science is thus prescriptive and in the context of management theory research would be developing technological rules to improve performance (van Aken, 2004). Iivari (2007) considers technological rules as guidelines for building complex DSR artefacts but also as such being artefacts themselves.

Hevner (2007) presents DSR as a process of three cycles: relevance, design, and rigor. The three cycles connect the problems observed in practice, which launches the design process, to the knowledge base. Similar processes of constructing artefacts (or other constructs) are presented in research discussing constructive research (e.g. (Kasanen, et al., 1991) for business research context) or systems development (e.g. (Nunamaker, et al., 1990-1991) for information systems context). Key to all these perspectives is that the artefacts, constructs or systems must have a basis in previous knowledge while also contributing to both practice and theory. As Iivari (2007, p. 13) calls it: “It is not enough for the artifact just to come out of the blue”.

DSR has been positioned as research paradigm (van Aken, 2004), strategy (van Aken, et al., 2016), methodology (Peffers, et al., 2007), and approach (McLaren, et al., 2011). This can be explained by the notion that the artefacts of design science can be on multiple levels and for different purposes. The previously mentioned technological rules are DSR artefacts but can also be methods used in further DSR processes. Iivari (2007) discusses the different ontologies and epistemologies design science can be based on. His perspective is on IT artefacts, which is relevant for this thesis. This thesis assumes the ontology that for the studied objects there may be one desired outcome, but the truth that can be observed is local for each studied object. Epistemology for this thesis is that the local truths can be understood through the construction of solutions that combine descriptive and prescriptive knowledge. The local truth is an interpretation of the studied object and the researchers, and as such there is bias in the context of using the constructed solutions. The local truths can be reached through induction. These assumptions position the thesis within the constructivist research paradigm (Peters, et al., 2013; Mir & Watson, 2000; Kasanen, et al., 1991). The thesis considers DSR as a research approach where a variety of methods are used to create artefacts to solve a class of problems.

**Current research process**

Peffers, Tuunanen et al. (2006) propose a six-step process for DSR. An adaptation of the process for this thesis is presented in Figure 3.1. There are multiple potential entry points for the research: problem-centred, objective-centred, design and development-centred, or context-initiated approach. Due to multiple potential entry points and the iterative nature of the process, the steps in the process are revisited and refined. For example, in the evaluation step, if the design artefact is determined not to be effective enough in solving the defined problem, the DSR process can revisit the design and development step to refine the artefact or solution step to propose a new solution artefact to be designed. DSR artefacts in the evaluation and communication phases must be able to solve the field problem in a generalised context while contributing to theory before the artefacts are validated.

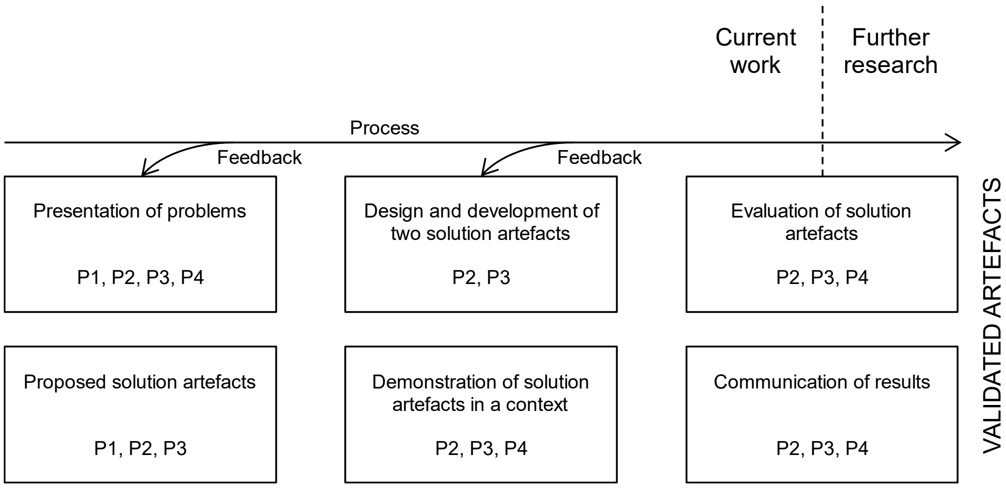


Figure 3.1 The DSR process of this thesis with publications relevant for each step.

The current DSR began from the presentation of problems and proposals for solution artefacts. The first identified problem was that the companies taking part in multilateral relationships in industrial maintenance networks (and later problem generalised to business ecosystems) are not comfortable in sharing information that is considered sensitive but play a crucial role in achieving cost benefits in business ecosystems. A proposed solution artefact for this problem was a serious game. A serious game combines entertainment traditionally associated with games with learning or training content. EcoGame was designed as a serious game with the goal of the business ecosystem actors playing together and reducing barriers of information sharing through improved collaboration. From a theoretical perspective, EcoGame is used to study the dynamic nature of business ecosystems through a simulation of collaborative decision-making in multilateral relationships. EcoGame has been demonstrated (Publication 3) by implementing a real business ecosystem profile within the game and playing it with master's level university students who have adopted the roles of the companies before playing the game.

The second identified problem originates from the need to profile an ecosystem within EcoGame and recognising that neither researchers nor the business ecosystem actors understand the structure of their business ecosystems. To implement a business ecosystem within EcoGame, the static nature of the ecosystem must be described. This includes recognition and positions of focal actors, relationships between ecosystem actors, and relevant individual information for each actor. The proposed solution artefact for these identified problems is a process to profile an ecosystem. The process artefact was designed and demonstrated using the same real business ecosystem that is used to demonstrate EcoGame. The process can be thought of as a technological rule for future artefacts, and that is the purpose of it. As EcoGame is already a working IT artefact, the Ecosystem Profile creation process artefact is the basis for an IT artefact and solution called Ecosystem Profiler. Ecosystem Profiler will automate the profiling process to minimise the required input from its users. The artefacts are presented separately in P2 and P3 but both are major contributions from the DSR process of this thesis.

The evaluation step of the solution artefacts is ongoing. The evaluation step includes the demonstration of validity, utility, quality and efficacy of the solution artefacts (Hevner, et al., 2004; Gregor & Hevner, 2013). These include considerations into the pragmatic validity and practical relevance of the solutions (van Aken, et al., 2016). Holmström et al. (2009) divide DSR into four phases and levels of contribution. The first phase is simply solving the practical problem the solution artefact is designed for. The second phase refines the solution artefacts to be efficient in solving the problem, still contributing to practice. The third phase moves on to theoretical contributions as in creating substantive theory with the solution artefact that is dependent on an empirical context. In the fourth phase, the solution artefacts are generalised for use and contribute to formal theory that is independent of a single empirical context. Gregor and Hevner (2013) similarly divide DSR contributions into three levels. First, a situated implementation of an artefact. Second, a nascent design theory. Third, a well-developed design theory. Different phases and levels of contribution require different types of artefacts, and a single DSR process can produce artefacts on multiple levels (Baskerville, et al., 2018; Gregor & Hevner, 2013; Holmström, et al., 2009).

The methods for evaluating the solution artefacts can be varied and typically chosen based on the knowledge base of the artefact (Hevner, et al., 2004). For EcoGame, the currently used evaluation methods include using a single case to gain repeated and comparable results from game sessions with different players. These tests have run annually since 2017. The evaluation of EcoGame also incorporates simulations of multilateral decision-making processes as a method, and its role will increase as the compatibility of EcoGame and Ecosystem Profiler improves. As an IT artefact, early stage evaluation of EcoGame also involved software related testing reported in my Master’s thesis (Rissanen, 2017). The development of Ecosystem Profiler is in an earlier stage than EcoGame, and thus the evaluation methods used so far are mainly descriptive, profiling different ecosystems and scenarios, for example the scenario of a new emerging ecosystem (see Publication 4). The future evaluation for Ecosystem Profiler takes a route similar to EcoGame, first with software related testing and then with multiple case studies. Repeating profiling on a single case provides reliability on how it captures the evolution of an ecosystem over time, and studying multiple cases provides reliability on how the profiler completes the profiling process (Publication 2).

The communication of results from demonstration and evaluation conducted so far are currently reported within Publications 2, 3 and 4 of this thesis and as research project reports (publicly funded research projects at LUT University called ReFaMo, ProDi, and ELPSU). Also, the results have been discussed in a number of workshops, seminars, conferences and other academic and managerial forums. The communication in those forums has been important as they have provided feedback on the improvement of artefact design. Further communication must take a larger role in the managerial side. The work within the DSR process of the artefacts is not concluded but continues with further applications in different contexts and for Ecosystem Profiler as turning the technological rule into an IT artefact. The two solutions (Ecosystem Profiler and EcoGame) are closely related and can be used together or separately. They are used separately to answer different problems in the field and contribute to different aspects of the nature of business ecosystems. Together they can provide an in-depth view to both the static and dynamic nature of a business ecosystem that can be used both for studying and improving the ecosystem.

## 3.2 Research methods

The research methods used in the publications discussed in this thesis are various but not conflicting within the research approach as DSR does not limit the usage of research methods. Each method used is concisely described, and they are listed by publications in Table 3.1.

Table 3.1 The research approach and methods applied in each publication.

| **Publication** | **Research approach** | **Research methods** |
|---|---|---|
| P1 | Review | Systematic literature review<br>Qualitative content analysis |
| P2 | DSR | Social network analysis<br>Web-farming |
| P3 | DSR | Simulation game<br>Survey |
| P4 | Mixed | Semi-structured interview<br>Survey |

**Systematic literature review** is used to identify, evaluate and interpret research that is useful in answering a set research question (Kitchenham & Charters, 2007). The purpose is similar to a traditional literature review conducted as part of most research. The goals can be summarising previous work in the field, extending theories, or assessing the work of others (Xiao & Watson, 2019). Systemising a literature review increases its replicability and transparency, and can lead to higher quality and validity (Kitchenham & Charters, 2007). Systematic literature review is the main research method in P1.

**Qualitative content analysis** turns textual data into quantifiable form (Luna-Reyes & Andersen, 2003). It is commonly used in social sciences to systematically analyse texts (Downe-Wamboldt, 1992). It is used in P1 to recognise recurring themes from the dataset consisting of scientific publications.

**Social network analysis** is used for analysis of social structures by using both qualitative and quantitative data (Tóth, et al., 2018; Badi, et al., 2017). It focuses on the relations between the actors of the social system (Scott, 2000). The results of the analysis are often presented in the form of visualisations that best capture the interconnectedness of the system actors (Carolan, 2014). P2 uses social network analysis jointly with web-farming to create a profile of a social structure that involves visualisation in a key role.

**Web-farming** turns business related information found in the web into knowledge that is useful in further analyses (Hackathorn, 1999; Masand & Spiliopoulou, 2000). Its purpose is to continuously gather data and improve the process of gathering (Lin, et al., 2020). Web-farming is used in P2 to test the profiling process by gathering data about the actors of the profiled ecosystem.

**Simulation games** can be used to study complex systems (Lukosch, et al., 2018). Social systems and games have much in common, which makes simulation a powerful way to combine the two in research (Klabbers, 2003a). Simulation games can have multiple purposes: training, teaching, experimentation, research, and operations (Lukosch & Comes, 2019). P3 presents the design and development of a serious game, which is used as a simulation game to gather relevant data from the social system it simulates.

**Surveys** are used to gather information systematically (Groves, et al., 2011). The questions asked in surveys can be used to gather answers in numerical form for quantitative research, or as open-ended questions for qualitative research (Ponto, 2015). The benefit of using surveys for research is to gain comparable answers from a large population. The survey used in P3 is quantitative, whereas the survey relevant for this thesis in P4 is qualitative. In the survey of P3, the answers were anonymous which increases their credibility, whereas in the survey of P4 the answers were anonymised together with the interviews.

**Semi-structured interviews** include pre-determined themes to be discussed with the interviewees. Each theme can consist of prepared questions and questions generated based on the discussion during the interview (Qu & Dumay, 2011). By structuring the interview, the credibility of the research is enhanced as the subjectivity of the interviewer is reduced (Horton, et al., 2004). Additionally, comparing and analysing multiple interviews is more systematic with structured data. Semi-structured interviews are the main data source in P4 as the surveys conducted for P4 were included in the interview structure.

## 3.3 Data collection

Data collected and used for the research conducted in each of the publications is presented in Table 3.2. As the research methods used for data collection and analysis are many, so vary the sources for data used in the publications included in this thesis. This also means that the data is of varying quality. Some of the data is objective, but most can include bias from the researcher or the people involved in generating the data. Bias is not a problem in constructivist research, but it must be acknowledged and reflected on.

Table 3.2 Data source, quality, and usage for each publication.

| Publication | Source | Quality | Usage |
|---|---|---|---|
| P1 | Scopus database | Scientific publications | Review of literature |
| P2 | Company and news websites<br>Amadeus database | Company self-publications, news articles and financial database | Business ecosystem profile creation |
| P3 | Game sessions; video and digital records<br>Student assignments<br>Survey | Student inputs in roles of companies<br>Graded student assignments<br>Anonymous survey | Structuring data for further research |
| P4 | Semi-structured interview<br>Survey | Anonymised research project interviews<br>Survey in conclusion and summary of discussion | Research project outcomes<br>Analysis of an emerging business ecosystem |

P1 consists of a systematic literature review where the research process is documented as transparently as possible to allow reproduction of the research. The data for P1 was gathered from the Scopus database. Scopus offers extensive indexing of research published in social sciences. Web of Science could have been an option to use instead or parallel to Scopus, but it was not found necessary at the time. Both databases are commercial products but considered most trusted for indexing of scientific research. The data itself consists of scientific journal and conference articles.

The data in P2 was collected from two different types of sources: company and news websites, and the Amadeus database. There is obvious potential for bias when a company reports its activities, but the web resources in P2 were mainly used to recognise relations between companies. Amadeus is a database that gathers financial and business information from European companies. The data is collected from company filings and reports by the publisher of the database. As the requirements and forms of reporting can vary by country, there can be inconsistencies in the database. Therefore, when using the financial information of companies in research, the primary source should first be the company filings and databases as secondary. In P2, the financial information of companies was primarily extracted from the Amadeus database and secondarily from company filings. This choice was made to reduce the work required as the Amadeus database was considered of sufficient quality in the context the data was used.

The data sources of P3 all involve the players of the game, master's level students. The students adopted the roles of the companies they represented in the game. This was controlled with a pre-game task to ensure that they had acquired the relevant knowledge on the simulated ecosystem. The game sessions were recorded as video and digital records from the game software. The digital records from the game software are comparable between different sessions, and most of it is numerical so it can be studied quantitatively. The video recordings are used to study the behaviour of the players, and for P3 the video data was analysed as observations made by researchers. This has potential for bias and is subjective by nature. In addition to game session related data, written reports by the players were used. These reports are graded assignments on the part of the players analysing the game play (i.e. collaborative decision-making and the dynamics of a multilateral relationship), but additionally they provided written feedback that was outside the graded submissions. Finally, a survey with both quantifiable and qualitative questions was conducted and the answers were anonymous. The reports and the survey involve potential bias from the students who answer the questions, and from the researchers as they set the questions. The questions for the survey were created referring to similar studies using games conducted previously to reduce bias.

Data for P4 was gathered during interviews with company representatives. The interviews were semi-structured, but the discussions were allowed to drift depending on the interests of the interviewee in each theme. However, all interviews went through the predetermined questions to allow comparability. The interviews were recorded and the results reported in anonymised form. During the interviews, two surveys were conducted. The second survey is relevant for this thesis, and it is qualitative by nature. The second survey also summarised the discussion, and therefore the additional topics discussed could have affected the answers of each interviewee. There is potential for bias from both the interviewers (i.e. researchers) and the interviewees as the semi-structured interview does not restrict the discussion as long as it remains within the pre-determined themes. The survey data however is not biased from the side of the researchers as it is in numerical form even though it is mainly analysed qualitatively.

All data gathered in the research included in this thesis is stored by LUT University and the access varies depending on the agreements made between different people involved in the research. Some data could be made publicly available if it were anonymised, and the data in P2 is publicly available and links to sources are included in P2.

# 4 Review of the results

## 4.1 P1: Existing serious games for decision-making processes

Publication 1, titled “Serious games for decision-making processes: a systematic literature review”, was set to provide information on how collaborative serious games are used for training in inter-organisational decision-making processes in business ecosystems. Serious games by definition transfer learning or training content via entertaining gameplay. They have been used to simulate complex systems and processes to provide insight into issues that are difficult to study, for example due to scarcity of observable events. My research recognises that business ecosystems are complex systems where decision-making processes are difficult to study. Therefore, it was necessary to understand how serious games have been used in other contexts to solve similar issues. A preliminary literature search did not provide much help, and thus a systematic literature review was conducted and reported as the first publication of my thesis.

The Scopus database was used for the review and main search with string “TITLE-ABS-KEY ((“serious game” AND “decision making”) AND NOT (“education” AND NOT “training”))” returned 197 results. The search excluded results with education as the main purpose of the serious game as they mostly referred to learning in schools. The 39 search results omitted as educational papers were screened separately from the main search, and one was included in the final sample. Three rounds of screening were conducted for the main search results, ending up with 23 papers included in the final sample to review and the one from screening of educational papers, totalling at a sample of 24 papers.

The games presented in the 24 papers were categorised by platform, amount of players, training content target, game genre, game subject, and the development stage of the game. The results of the categorisation are shown in Table 4.1. The 24 papers studied discussed 20 different games. For example, game 4 was discussed in four different papers and therefore it has four entries in the table. The games were also categorised by how rational decision-making phases occurred within the decision-making situations presented in the games.

Table 4.1 Categorisation results for systematic literature review conducted (P1).

| Topic | Game platform | | Amount of players | | Training content for | | Game genre | | | | Subject of the game | | | | | Stage of the game (at the time of publication) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Digital | Non-digital | Single player | Multiplayer | Single organisation | Inter-organisational | Simulation | RPG | Quiz | Other | Healthcare | Military | Conflict management | Airport management | Other | Concept | Prototype | Validated | Released |
| 1 | x | | x | | x | | | 1 | | | | | | | 1 | | | x | |
| 2 | x | | x | | x | | 1 | | | | 1 | | | | 2 | | | x | |
| 3 | x | | | x | x | | 1 | | | | | | | | 1 | x | | | |
| 4a | | x | | x | | x | 2 | 1 | | | | | | 1 | | x | | | |
| 4b | | x | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 4c | | x | | x | | x | 2 | 1 | | | | | | 1 | | | | x | |
| 4d | | x | | x | | x | 2 | 1 | | | | | | 1 | | x | | | |
| 5 | x | | | x | x | | 1 | | | | | 1 | | | | | | | x |
| 6 | x | | x | | x | | 2 | 1 | | | 2 | | 1 | | | | x | | |
| 7a | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 7b | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 7c | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 8 | x | | x | | x | | | | 1 | | 1 | | | | | | x | | |
| 9 | x | | x | | x | | | | 1 | | | | | | 1 | | | x | |
| 10 | x | | x | | x | | 1 | | | | 1 | | | | | | | x | |
| 11 | | x | | x | | x | 2 | 1 | | | | | 1 | | | | x | | |
| 12 | x | | | x | x | | 1 | | | | 1 | | | | | | x | | |
| 13 | x | | x | | x | | 1 | | | | | | 1 | | | x | | | |
| 14 | x | | x | | x | | | 2 | | 1 | 1 | | | | | | x | | |
| 15 | x | | x | | x | | 2 | 1 | | | | | | | 1 | | x | | |
| 16 | x | | x | | x | | | | 1 | | | 1 | | | | | x | | |
| 17 | x | | x | | x | | | | | 1 | | 1 | | | | | x | | |
| 18 | x | | x | | x | | 1 | | | | 1 | | | | | | x | | |
| 19 | x | | x | | x | | 1 | | | | 1 | | | | | | x | | |
| 20 | x | | x | | x | | 1 | | | | | 1 | | | | | | | x |

Qualitative content analysis was used for the 24 papers to gain understanding on the overall themes and topics discussed in the papers. As a visualised result, a word cloud was created as seen in Figure 4.1. The content analysis revealed (occurrence in brackets) that ‘collaboration’ (307) and ‘cdm’ (i.e. collaborative decision-making, 242), that are central to the overall work of my thesis were far from the most frequent terms in the papers. The most frequent ones that were not included in the search string were: making (1607), design (1456), process (1228), work (1170), take (1061), results (1060), study (993), performance (972), player (899), control (840), management (830). Of these, performance, control and management stand out as topics of interest for the contexts of the serious games.


Figure 4.1 Word cloud as a result of content analysis (P1).

Publication 1 showed that interest towards using serious games, and games in general, for research and training was increasing. Especially since new technologies offer new ways to create more realistic simulations or entertaining experiences to include in games. The paper resulted in understanding on how serious games are used for decision-making processes within a single organisation but not much on how they are used in inter-organisational collaborative structures like business ecosystems, as only three out of twenty reviewed games involved an inter-organisational setting. The analysed games mainly presented decision-making where the situations were already established (e.g. decisions during active crisis, decisions during healthcare related operations), rather than the players having to first establish the decision-making situation while managing a larger context. The games did not contain any existing solutions that could have been transferred to my research context but provided inspiration and showed that there is value in applying a serious game solution to the business ecosystem context as the study did not find such applications.

## 4.2 P2: Profiling process to make sense of complex ecosystems

Publication 2, titled ‘A Web of Clues: Can Ecosystems Be Profiled Similarly to Criminals?’, was set to study how the ecosystems of organisations could be profiled to better describe their operations and guide actors in managing their ecosystems. In the design process of the DSR artefact, the paper draws inspiration from existing profiling solutions in the field of criminal investigation. Business ecosystems have been previously mapped and visualised, but the combined effort of visualising the actors and their relations and combining it with actor-specific information allows deeper analysis of the static structure of an ecosystem.

The paper uses the DSR approach for the creation of the profiling process solution artefact and social network analysis (SNA) and web-farming as research methods. A social network consists of actors, links and flows, and SNA emphasises the systematic collection of data and visualising the social network. Web-farming emphasises the collection of business-related data from the internet and turning it into relevant knowledge. Figure 4.2 illustrates the Ecosystem Profile creation process created within the DSR of Publication 2.

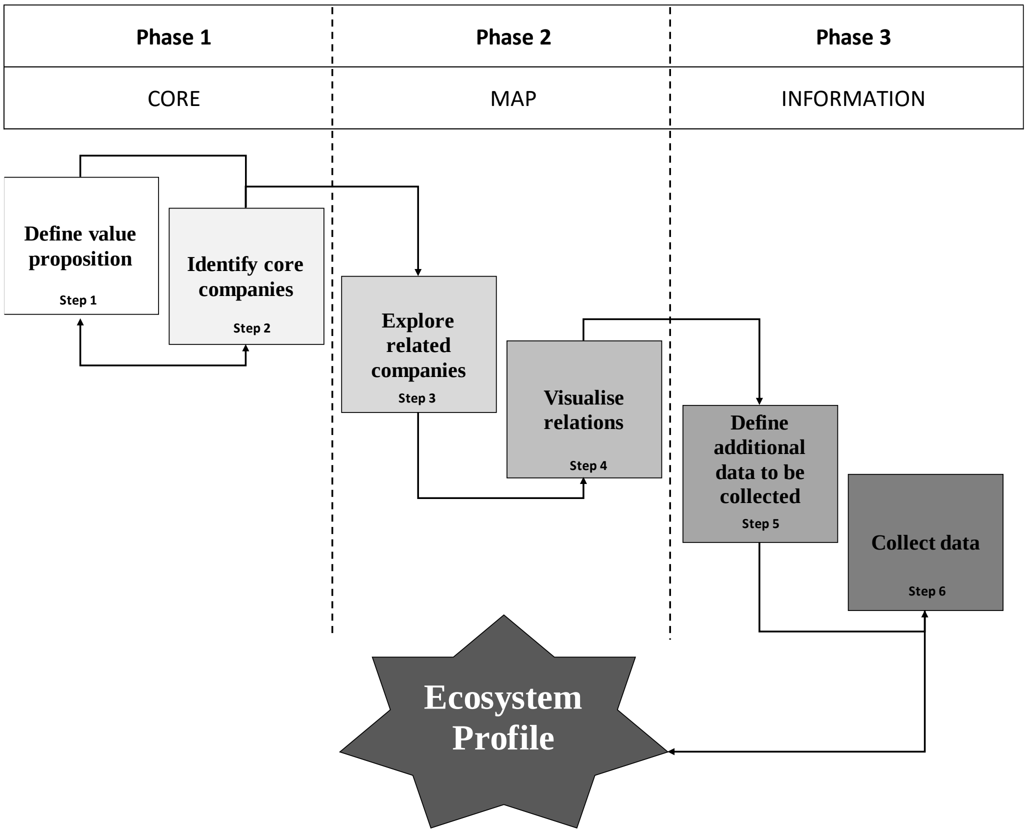


Figure 4.2 Ecosystem profiling process (P2).

The Ecosystem Profile creation process is divided into three phases, each of them consisting of two steps. The first phase 'CORE' involves defining the value proposition of the business ecosystem and identifying the core companies, focal actors, of the ecosystem. The steps in the first phase can be conducted in either order, or even multiple times to gain as accurate understanding of the core of the business ecosystem under study as possible. In the second phase, 'MAP', a visual presentation in the form of a map of the business ecosystem is created. First the core of the ecosystem is expanded to recognise and explore companies that are closely associated with the delivery of the ecosystems value proposition. After the related actors are recognised, they and their relations are visualised. Third and the final phase is called 'INFORMATION'. After mapping the ecosystem, the profiling process goes into depth into the individual actors and their data relevant for the ecosystem. First the data to be collected is defined and finally collected. The defining is crucial, since the amount of actors and data available of them can be enormous and without clear boundaries, the data collected will not aid in the goal of making sense of the ecosystems structure.

The three phases of Ecosystem Profile creation result in a profile that combines visual, quantitative and qualitative information about the studied business ecosystem and its actors. The created process was tested and the results discussed in Publication 2. The case to test the ecosystem profile process involved both a central value proposition and a strong focal actor in the forestry machine industry. The profile captured ecosystem actors and connections in a visual form (see Figure 4.3) and additionally in the forms of financial information and qualitative public information of the activities of the actors contributing to the business ecosystem. Figure 4.3 presents the visual map and structure of the profile of the case ecosystem, but only includes the focal actors by name for clarity. The unnamed actors in the figure are coloured to group them as sub-ecosystems or networks of individual focal actors.

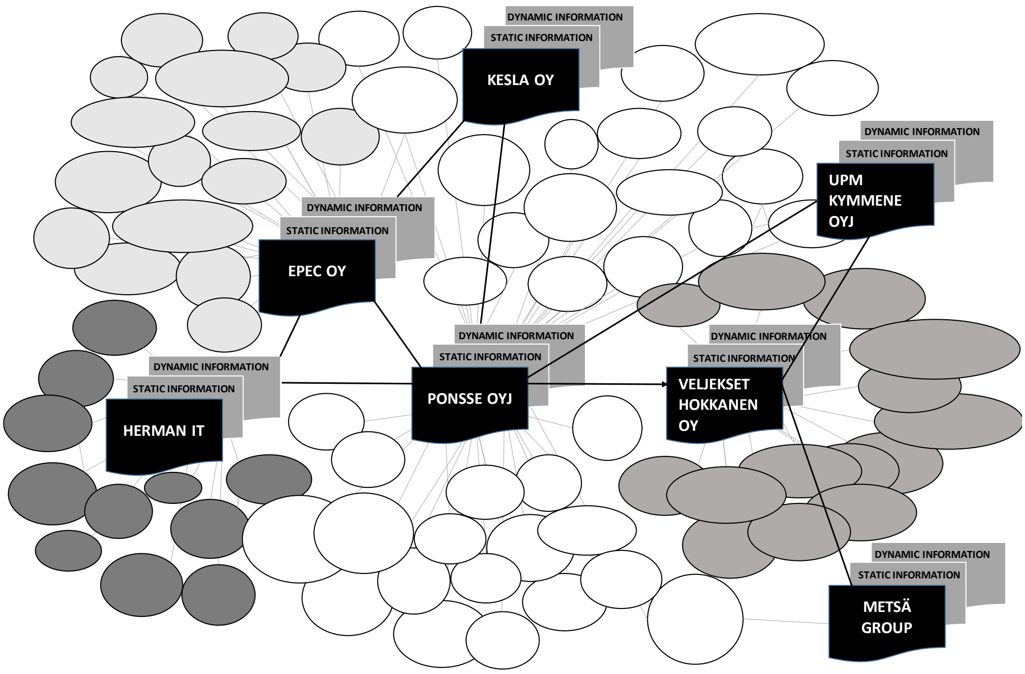


Figure 4.3 Visual part of an ecosystem profile (P2).

The studied case revealed connections within the profiled ecosystem that are not necessarily expected, and thus provided useful information for further research. The relation in question was Epec Oy, who is a subsidiary of Ponsse, having a connection to Kesla Oy, who is a competitor to Ponsse on some segments. Considering the nature of the industry on a national scale, it comes as a surprise that competitors would have a connection so close, even though competition is a recognised characteristic within ecosystems. The Ecosystem Profile creation process therefore revealed insight into the studied ecosystem structure that was not expected, and thus worked as intended. For a researcher, the new insights give further understanding on ecosystems' behaviour but for the actors within the ecosystem, additional insight can be valuable in relation to co-evolution and co-creation activities.

## 4.3 P3: Serious game to study and improve business ecosystems

P3, titled "The dilemma of studying multilateral relationships: EcoGame as a solution", presented the DSR process of EcoGame, a serious game to study the dynamic nature of business ecosystems and improve collaboration in the multilateral relationships of ecosystem actors. The paper was set to uncover data relevant for the twofold purpose of the game. This was done through multiple sets of testing the game with master's level students while simulating a real multilateral relationship within the game.

The DSR of EcoGame adopted the cyclic process presented by Hevner (2007) and can be seen in Figure 4.4. The motivation for the creation of EcoGame as a DSR artefact is drawn from the environment through the relevance cycle. The design of EcoGame is grounded in knowledge gained through the rigor cycle. The design cycle continuously communicates with both rigor and relevance cycles to ensure that the final product can be used both for further research in the field of knowledge and to improve the initial field problem observed in the environment.

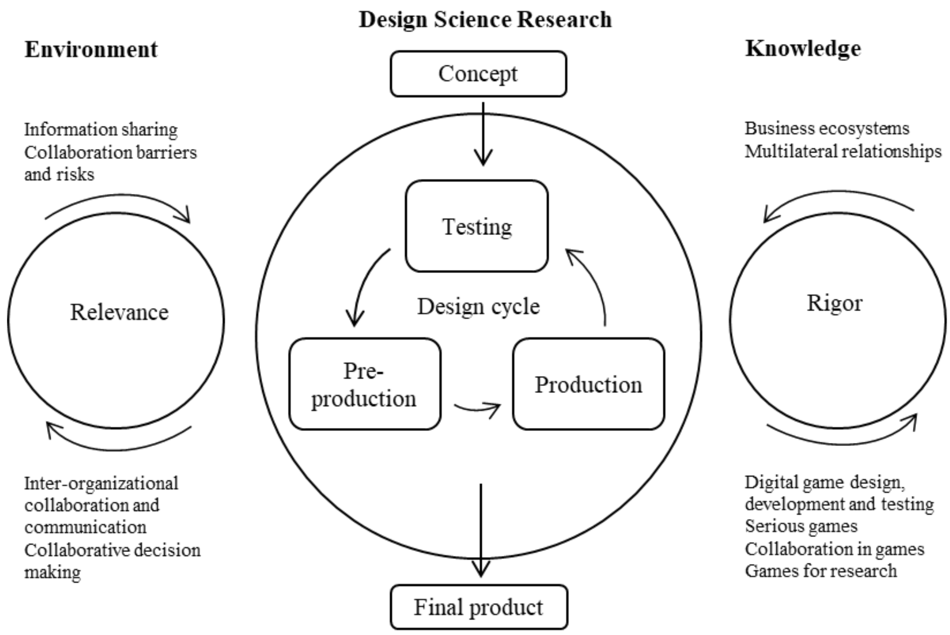


Figure 4.4 Three-cycle DSR for EcoGame (P3, adapted from Hevner, 2007).

The testing of EcoGame discussed in P3 is conducted with students but some of the data collected with the game is also considered relevant for studying the dynamic nature of real multilateral relationships of business ecosystems. This is achieved by incorporating a profile of a real business ecosystem in the game and engaging the playing students into the roles of the ecosystem actors. The four phases of playing EcoGame are presented in Figure 4.5. When EcoGame is played by the real ecosystem actors, the phases are the same but the element of role adoption is more about discussing how the profile of the playable ecosystem was implemented in EcoGame. The first two phases prepare the game and the players for the third phase, player interaction and gameplay. It involves the players representing three ecosystem actors of a multilateral relationship where each actor has individual resources. The players have individual and common goals which they work towards by engaging in collaborative decision-making which requires information sharing about their available resources. The game promotes collaboration but does not restrict competition as both are important for the co-evolution of business ecosystems. The game sessions are recorded, and facilitators make observations throughout the play to have the data available for further research and not only for training.

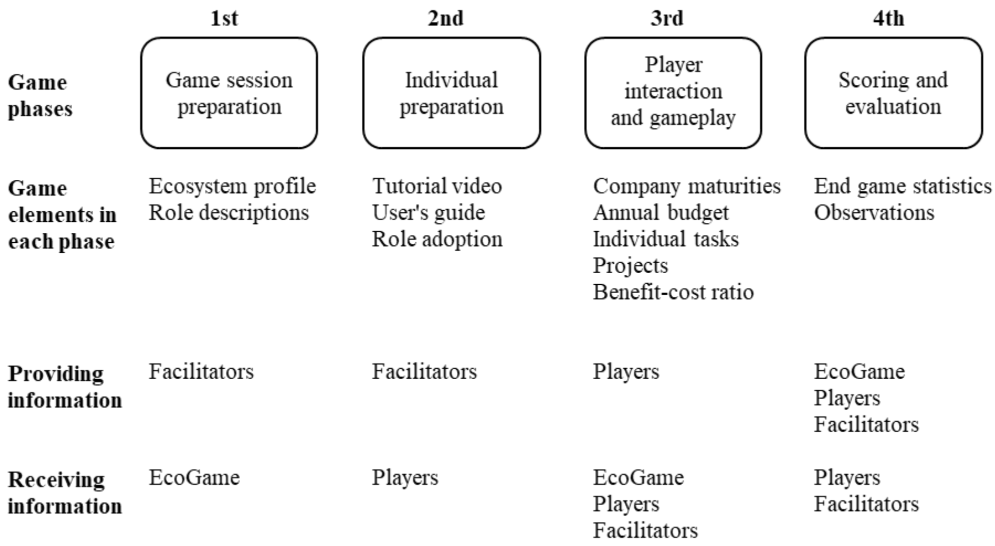


Figure 4.5 EcoGame phases, elements and information provided and received by the game and participants of a game session (P3).

The results reported in P3 were gained in four rounds of tests conducted between 2017 and 2020. In total, 194 students have so far participated in the tests and 40 game sessions have been played. The data gathered throughout the tests have evolved over the years as the design cycle continues to refine the EcoGame as a DSR artefact. The data gathered with the conducted tests and found relevant for research into the dynamic nature of the business ecosystem is presented in Table 4.2. The data can contribute to all three cycles of the DSR process of EcoGame leading to reaching the final product of EcoGame as part of further research. Further research with EcoGame includes generalising the use of EcoGame in other contexts and evaluating the quality of the collected data in comparison to other research methods used for similar issues.

Table 4.2 Topics relevant for research by game phase and nature of data (P3).

| | **Qualitative** | **Quantitative** |
|---|---|---|
| Game session preparation | Project and task contents<br>Project and task parameters | Financial state of ecosystem<br>Company maturities |
| Individual preparation | Ecosystem structure<br>Analysis of collaboration, trust and power relations<br>Potential collaboration strategies<br>Feedback about game and role adoption | |
| Player interaction and gameplay | Player behaviour<br>Communication<br>Development of collaboration | Benefit-cost ratios<br>Project and round durations<br>Technical events |
| Scoring and evaluation | Analysis and reflection on strategies and results of second session<br>Feedback about game, its use for learning and its capabilities on simulating reality | Survey data on understanding of ecosystem concept, learning with EcoGame and user experience of playing EcoGame |

## 4.4 P4: Two potential structures of an emerging ecosystem

P4, titled ‘Recognizing Life Cycle Benefits of Real Time Fatigue Monitoring for Ecosystems’, reports the results of semi-structured interviews conducted in the research project called ReFaMo (Real-time Fatigue Monitoring of welded steel structures). The purpose of the interviews was to find out how the different actors of a new potential ecosystem understand the benefits of the new product and how they see the new emerging ecosystem and its actors. The new product discussed in the interviews offered real-time monitoring of a welded steel structure while providing information on its remaining life. The interviews were conducted as seven semi-structured interviews divided into four themes and including two surveys to be filled out to summarise the discussions. The themes were: Product, Data, Value, and Business Model. The first survey was conducted as part of ‘Value’ and concentrated on the perceived benefits, and the second survey as part of ‘Business Model’ to visually outline the actors the interviewees saw as focal actors in the emerging ecosystem. The interviewees were companies involved in different parts of the life cycle of the welded structure. Table 4.3 lists the interviewees and their backgrounds, and Figure 4.6 displays how they positioned into the life cycle of welded structures.

Table 4.3 Interviewees and their fields of business (P4).

| **Field of business** | **Company** | **Title of interviewee** |
|---|---|---|
| Construction engineering | A | Senior structural expert |
| Maintenance and engineering services | B | Maintenance manager |
| Power plant operation | C | Investment portfolio manager |
| Civil engineering | D | Bridge specialist |
| Heavy equipment production and services | E | Test engineer |
| Heavy equipment production and services | F | Research and development manager |
| Power plant operation | G | Managing director |
| Power plant operation | G | Project manager |

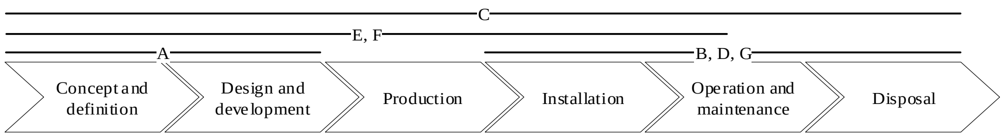


Figure 4.6 Life cycle of an item and the involvement of the interviewed companies in it (P4).

In the context of this thesis, the main findings of P4 relate to the second survey and discussions related to theme ‘Business Model’. Figure 4.7 displays two different results from the surveys on how the interviewees would structure the emerging business ecosystem. The answers from company A are not included as they did not see themselves as a focal actor in the emerging ecosystem, but their presentation of the ecosystem would have been more in line with companies B, C, D and G. Both ecosystem types consider the customers of the interviewee as focal within the ecosystem, but the ecosystem of companies B, C, D and G also includes the provider of the ReFaMo product. The ecosystem of companies E and F would not involve any service providers as focal actors as the companies themselves wanted to provide services related to the discussed welded steel structures. They were also hesitant to share any information gained through services like ReFaMo within the proposed ecosystem. This can be seen as dominant strategy by the companies as they would engage in more competitive than collaborative relationships within their ecosystem. Companies B, C, D and G in turn were very open to more collaborative relationships between different ecosystem actors and sharing information to optimise ecosystem co-creation activities among multiple actors.

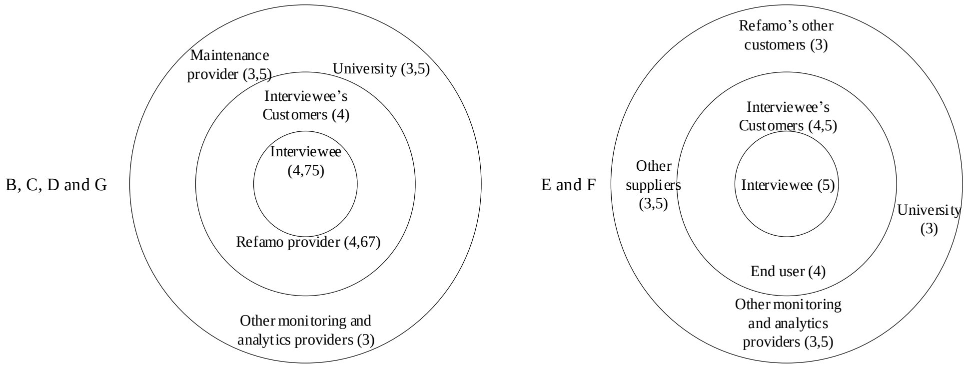


Figure 4.7 New Refamo ecosystems for each category (P4).

The two different positions taken by the interviewed companies considering the ecosystem structure can in part be explained by the role the interviewees currently hold in providing the discussed welded steel structure and services associated with it. Companies E and F create most of the value associated with the discussed structure in the form of manufacturing the structure and providing services related to it. Companies B, C, D and G play a smaller role within the discussed structures. They may be the ones manufacturing, maintaining, or owning the discussed structures, but as their role in the ecosystem is narrower, they are more open to collaboration with new actors. The results of P4 reflect the literature on business ecosystems where many of the studied case ecosystems are built around a strong focal actor and the ecosystems consist of recognisable supply or value chains. The focal actors (interviews E and F) are primarily looking at holding on to their positions and see that increased openness and collaboration could harm that. Instead of accommodating niche players into key roles within their ecosystem, they look to acquire emerging key functions within their organisation. The focal actors in the other category of an emerging ecosystem (interviews B, C, D and G) see more potential for improved collaboration and openness within the ecosystem. As focal actors, they would not have as big of a role in the emerging ecosystem as companies E and F, and thus see the potential benefits of collaboration outweighing the risks. These results provide an important context for studying the profiles of different ecosystems and understanding the behaviour of actors playing EcoGame.

## 4.5 Discussion

The business ecosystem is a complex and dynamic system characterised by the co-evolution of the ecosystem actors and the co-creation of value towards a common value proposition (Peltoniemi, 2005). P4 showed that the two types of business ecosystems (Adner, 2017), one where the ecosystem is focal actor-centric and one where the value proposition is central, are both very relevant. The focal actor perspective in P4 is more closed even though the two different approaches to business ecosystems do not exclude each other. Based on the interviews conducted for P4, factors that can affect how the actors see their ecosystem are for example local competition, market size, and availability of technology. Actors accustomed to collaborating in other ecosystems or other inter-organisational structures find business ecosystems originating from the common value proposition more desirable. Actors whose goal is to centralise most of the value creation activities inside their company are more reluctant to allow a business ecosystem to be formed where they are not the only focal actor and where they would not control the delivery of the value proposition. In this case, ecosystem management is characterised by the strategies of the focal actor (Iansiti & Levien, 2004), whereas in the former case the management is part of collaborative decision-making in multilateral relationships between focal actors (Wulf & Butel, 2017). Ecosystem research can therefore contribute to strategy research, as also mentioned by Jacobides et al. (2018).

By continuous co-evolution, business ecosystems are able to compete against other ecosystems and individuals in rapidly developing markets. In conservative and extremely regulated markets, organising as business ecosystems can be redundant as co-evolution is not a priority and value co-creation is controlled with regulations making competitiveness not depend on innovations. An example of this is the ship building industry which was discussed in one of the interviews conducted in the ReFaMo-project and results presented in P4. In turn, markets where technologies develop fast, for example consumer electronics, companies benefit from organising as business ecosystems to co-evolve and renew each time the market of their value proposition reaches the end of its life (Moore, 1993; Rong & Shi, 2015). Here it is worth noting that business ecosystems can exist parallel to other types of ecosystems – such as innovation or knowledge ecosystems (Valkokari, 2015). If the role of customers in the business ecosystem is small, or organising as business ecosystem is otherwise redundant, co-innovation and knowledge creation in parallel ecosystems and thus ecosystem thinking can still be relevant.

Business ecosystems from various markets and disciplines have been studied and presented in scientific publications as visualisations and maps. The presentations are often static and concentrate on the focal actors and their relationships within the ecosystem at one point in time (Jacobides, et al., 2018). The view is focused and narrow to gain insight into the centre of the ecosystem where most of the value co-creation activities are located (Iansiti & Levien, 2004). The actors far from the focal point of the ecosystem are not necessarily relevant to the overall performance of the ecosystem even though they do provide for the common value proposition. However, narrowing the focus to only a few actors may cause the presented structure to look like something other than a business ecosystem, for example a cluster or a value network.

The static nature of a business ecosystem is important to comprehend as a starting point for studying the dynamic nature. The dynamic nature of a business ecosystem describes the activities conducted between ecosystem actors, which leads to the co-evolution of the ecosystem over time. Capturing the static nature over time can lead to dynamic understanding on the structural changes within the business ecosystem (Basole, 2014), but different solutions are required to build understanding on the dynamic nature consisting of for example the behaviour of ecosystem actors during collaborative decision-making. Collaborative decision-making is central to co-creation in business ecosystems as ecosystem actors minimise the number of overlapping activities between individuals and rather complement each other in optimised operations. Therefore, co-creation activities within business ecosystems are constant collaborations in multilateral relationships.

**Ecosystem Profile and EcoGame as solutions**

By recording and presenting both the static and dynamic nature of a business ecosystem, the ecosystem can be presented in a way that best captures the complex system. Solutions like Profiler and EcoGame are one step towards this, and there is call for more solutions as the dynamics of the co-evolution of business ecosystems is still to be studied (Rong, et al., 2018). When a company acknowledges taking part in a business ecosystem and acts accordingly, they will be engaging in multilateral relationships including collaborative decision-making situations. For the relationships to work and the business ecosystem to fulfil its purpose of delivering the value proposition better than competing ecosystems or individual actors, the actors must share information required for decision-making and optimising resources (Pera, et al., 2016). To conquer the barriers related to collaborative decision-making, Ecosystem Profiler and EcoGame were designed and more solutions are expected to come in further research.

Ecosystem Profiler is used to pattern a business ecosystem. This includes recognising the value proposition the ecosystem provides and the identification of the core companies, focal actors. The centre of the ecosystem is then extended to include other actors that provide to the value proposition (Moore, 1996). The relationships of the business ecosystem are visualised as a map , and as a final step in the process, data on individual companies are gathered and in-depth conclusions on how the individual companies position in the ecosystem are made (Basole, et al., 2016). The goal of an Ecosystem Profile is to understand the static nature of the ecosystem under study, including the relationships between the actors and the compatibility of the actors.

EcoGame implements a real business ecosystem profile to simulate collaborative decision-making in multilateral relationships. When the game is played by the real representatives of the simulated business ecosystem, the game is used to study and improve the collaboration of the playing actors, both as organisations and individuals

(Lukosch, et al., 2018). Collaboration barriers are related to inter-organisational or interpersonal trust. In a business ecosystem, decision-making situations can come scarcely and thus the decision makers have not been able to build the trust through continuous collaboration and long-term engagement. In addition to ecosystem collaboration, these issues relate to ecosystem coordination and governance (Jacobides, et al., 2018). EcoGame breaks collaboration barriers by simulating collaborative decision-making situations and allowing the decision makers to build trust.

The Ecosystem Profile can be directly linked to EcoGame as a starting point. The joint use of the two solutions works as an extensive solution to address the lack of research into multilateral relationships of business ecosystems and decision-making within, and improve the management business ecosystems (Jacobides, et al., 2018; Rong, et al., 2018). Joint use is a natural outcome because both solutions emerge from the same DSR presented in this thesis. First it was recognised that collaboration is lacking and we needed a DSR process to solve that problem. Then it was discovered that the companies as well as us researchers lack knowledge on how the relationships of business ecosystems form and how they behave and why. Ecosystem Profiler is used to create this understanding, both for research and management. By understanding why the actors behave as they do, EcoGame can be used to improve the initial situation. EcoGame can then again highlight issues that are worth noting when analysing the results of further Profiling.

**Results**

The purpose of this thesis was to create Design Science Research artefacts as solutions for understanding and managing the static and dynamic natures of business ecosystems, and the main contributions from each publication for this thesis are summarised in Table 4.4. The thesis was also set to answer three research questions. A summary of how each of the research questions were answered with the publications is discussed below and the connections from publications to both the DSR process and the research questions are presented in Figure 4.8.

Table 4.4 Main contributions from each publication in the context of this thesis.

| | | |
|---|---|---|
| **Theoretical contributions** | P1 | Current state of usage of serious games in training of decision-making |
| | P2 | Ecosystem profiling and its uses for presenting the static nature of a business ecosystem and capturing co-evolution through a series of profiles |
| | P3 | Serious game incorporating simulation of collaborative decision-making and data for research on the dynamics of multilateral relationships in business ecosystems |
| | P4 | Focal actor perspectives towards organising in an emerging business ecosystem |
| **Managerial contributions** | P1 | Potential of serious games in organisational training of decision-making |
| | P2 | Ecosystem profiles to create understanding on the structure of ecosystems and to support ecosystem management |
| | P3 | EcoGame to improve collaboration and collaborative decision-making in multilateral relationships of business ecosystems |
| | P4 | Different potential ecosystem approaches for different types of ecosystem focal actors |

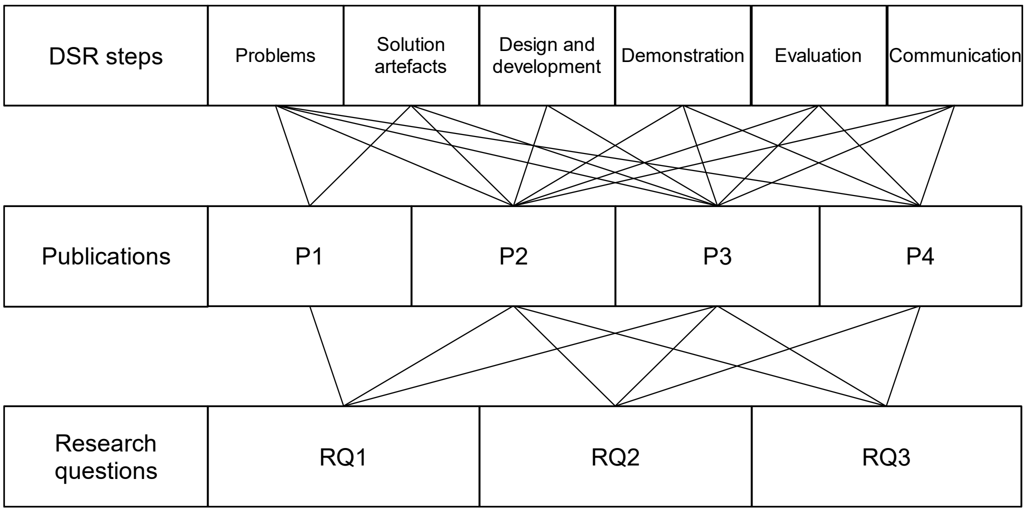


Figure 4.8 Connections from publications to the DSR process steps and the research questions.

*RQ1. Which solutions can be used in studying business ecosystem management?*

Serious games and profiling processes are studied as potential solutions for studying the nature of business ecosystems as a part of the DSR process step “Proposed solution artefacts”. Serious games are found to be used for training of organisational decision-making but not in the context of business ecosystems. However, serious games incorporating simulation are successfully used to study and improve processes in other complex dynamic systems. For a part of the profiling process, visualising and mapping the structure of an ecosystem are considered. Visual presentations are also prevalent in the literature of business ecosystems. Additionally, criminal profiling process is used to draw inspiration to propose a similar process for creating an ecosystem profile. Other potential solutions presented in business ecosystem literature are also considered. However, many of them are conceptual and require most of the inputs from the ecosystem actors, and therefore do not create new insights. They can be useful for managerial purposes but less for research. For studying topics related to business ecosystem management, EcoGame and Ecosystem Profiler solution designs are proposed based on previous literature on serious games and profiling.

*RQ2. How are the solutions created as DSR artefacts?*

The individual DSR-processes for EcoGame and Ecosystem Profiler are described in Publications 2 and 3. The overall DSR-process for the creation of the solutions as DSR artefacts is in six steps: presentation of problems, proposed solution artefacts, design and development of two solution artefacts, demonstration of solution artefacts in a context, evaluation of solution artefacts, communication of results. Currently the solution artefacts are demonstrated in a context and initially evaluated. They must be rigorously evaluated to be able to solve the problems that initiated the DSR process while also contributing to the knowledge bases of the solutions. A validated solution artefact is one that is not context dependant and contributes managerially and theoretically.

*RQ3. What is the contribution of the solutions to knowledge base, consisting of ecosystem patterning, management, solutions, and performance?*

EcoGame contributes to its knowledge base in the topics of serious games, collaborative decision-making, and multilateral relationships. These are topics under ecosystem patterning, management, and solutions. The contribution is in the form of demonstrating the viability of a serious game in a business ecosystem context and providing data to study the dynamic nature of business ecosystems. The contribution of Ecosystem Profiler is in the form of applying a profiling process from a different context for business ecosystems and creating static presentations of business ecosystems. These contribute to ecosystem patterning, management, and solutions as well through the topics of maps and visualisations, ecosystem actor roles and relationships, and potential risks and benefits. Additionally, the joint use of the solutions contributes to ecosystem performance by providing a comprehensive look into the nature of business ecosystems both for ecosystem researchers and managers.

# 5 Conclusions

## 5.1 Contribution

Overall, the main contributions of this thesis are the two solution artefacts, EcoGame and Ecosystem Profiler. The theoretical and managerial contributions of this thesis through those solution artefacts are summarised in Table 5.1.

**Theoretical contributions to the knowledge base of EcoGame.** First, serious games were found to be used in training decision-making but not in a multilateral inter-organisational context such as business ecosystems. EcoGame demonstrates that a serious game can be used in such contexts. Second, EcoGame also answers the call of creating more understanding on the dynamic nature of business ecosystems by generating data from the gameplay to further study issues related to collaborative decision-making, information sharing, and the benefits and risks associated with business ecosystems. Third, solutions for business ecosystems were generally found to require a lot of input from the ecosystem actors, and thus have a lesser chance of creating new knowledge, while the focus is on revealing information that is not evident. EcoGame utilises information gathered through a profiling process to simulate the ecosystem within the game. This way the players do not need to focus on creating the input but instead on creating the output.

**Theoretical contributions to the knowledge base of Ecosystem Profiler.** First, the process of criminal profiling was used as an inspiration to create a process to profile a business ecosystem. While the criminal profiling process is not a DSR artefact, a successful adaptation in the context of DSR is useful for further adaptations to different fields. Therefore, the adaptation itself is an important contribution. Second, Ecosystem Profiler creates a comprehensive presentation of the static nature of business ecosystems. This includes highlighting the value proposition, focal actors and other relevant actors, their positions and relationships, and the individual information of actors playing a key role in realising the value proposition. Previous solutions for static nature have concentrated on visual presentations, but Ecosystem Profiler combines multiple types of information.

Table 5.1 Key contributions of EcoGame and Ecosystem Profiler.

| | | |
|---|---|---|
| **Theoretical contributions** | EcoGame | A serious game solution in a multilateral decision-making context |
| | | Generating data to study the dynamic nature of business ecosystems, including collaborative multilateral decision-making and the benefits and risks involved |
| | | Creation of ecosystem information through playing |
| | Ecosystem Profiler | Adaption of criminal profiling process to the field of business ecosystems |
| | | Comprehensive presentation of the static nature of business ecosystems, including value proposition, actors, their positions and relationships, and individual information of key actors |
| **Managerial contributions** | EcoGame | Testing and improving collaboration in different multilateral relationships |
| | | Demonstrating effects of information sharing in multilateral context, and potential benefits and risks involved |
| | | Reducing barriers related to lack of previous collaboration between actors |
| | | Playing scenarios of business ecosystems that are emerging |
| | Ecosystem Profiler | Profile to be used to support management of existing ecosystems through gathering relevant information and displaying the value proposition and relationships between actors for the whole ecosystem |
| | | Comparing alternative ecosystem profiles in the case of an emerging ecosystem |

**Managerial contributions through the use of EcoGame.** First, EcoGame is used to test and improve collaboration in different multilateral relationships. The various relationships can be different ones from within the ecosystem, or one multilateral relationship can test changes to collaboration dynamics by changing a single actor to a different one. For example, two companies need a new supplier and they test collaboration dynamics with several alternatives. Second, through playing EcoGame, the actors realise the effects of information sharing in a multilateral context. They have not been sharing sensitive information previously within the relationship, but in the game they can share it in a simulated risk-free environment and see how the potential benefits and risks involved realise. Third, EcoGame can reduce barriers of collaboration that exist because the relationship is new or the actors do not otherwise have a history of collaboration. The lack of previous collaboration can be seen as a lack of trust between the actors, and in multilateral relationships lack of trust is difficult to solve with formal contracts. Additionally, in the games played so far, dynamics involving losing trust in a new multilateral relationship have been observed. Fourth, different scenarios involving emerging ecosystems around, for example, a technical innovation can also be played. These scenarios provide information on how a new company would develop through collaboration in an emerging ecosystem, or how the innovation would be developed by existing ecosystem actors.

**Managerial contributions through the use of Ecosystem Profiler.** First, the created ecosystem profile can be used to support ecosystem management by gathering relevant information and revealing actors, relationships, or other information that has not been evident to the focal actors of the ecosystem. For a business ecosystem, it is key that the actors contribute to a common value proposition. The ecosystem profile can help refine the value proposition and ensure that the ecosystem is truly working towards the common value proposition. Second, in the case of an emerging ecosystem, Ecosystem Profiler can be used to create alternative profiles that can then be compared. The comparison can provide information that leads to a choice of collaboration between actors that is predicted to lead to the best possible performance.

## 5.2 Evaluation

In DSR, the created artefacts are validated as a result of finishing the DSR process. The validity means that the solution artefacts reliably produce the results they are designed for. The design of the artefact is bound to change through feedback even during the evaluation phase of DSR, and thus validity cannot be completely determined until the DSR process is finished. The reliability of the solution artefacts goes through rigorous testing, showing that the results from repeated tests are comparable and thus reliable. The results gained with the use of a DSR artefact can contribute on one or multiple levels – from managerial results on a narrowly defined context to contributing to formal theories, and levels in between.

EcoGame has so far been tested annually with master’s level university students since its original design in 2017. Results from individual years are fully comparable with each other. Some changes in the design over the years have also evolved the results that are gained, and therefore not all test results are comparable between the years of testing. The validity of the results has increased over the annual test rounds as the design has been improved through developments in research on ecosystems and feedback and learning results from the players. As the current games are played by students, the validity of the data gathered with it is analysed by comparing it to games played by real ecosystem actors in the future. Some of the games played with students involved players with long work experience in positions relevant to the game setting. The results from those games work as an intermediary between games played by students and real ecosystem actors. Most of the current results from EcoGame come from a game setting in a single context. It is designed to be able to implement different types of ecosystems generated by Ecosystem Profiler, and thus the aim of EcoGame is to be able to contribute to formal theories about ecosystem management and performance.

Ecosystem Profiler is much younger in its design and, so far, the process of profiling has been tested on the case reported in Publication 2 and a few other ones. The reliability of the results is not on the level of EcoGame, but the evaluation methods for Ecosystem Profiler are different either way. While EcoGame can improve its design and the validity of its results through repeated plays of the same game, Ecosystem Profiler will improve through repeating the profiling process on different ecosystems. Profiling different types of ecosystems will reveal potential requirements for changes to the profiling process. The aim of Ecosystem Profiler is to use a single process to profile any business ecosystem and contribute to formal theories related to ecosystem patterning.

The joint use of the solutions aims at the improvement of ecosystem performance and contributing to formal theory creation related to that. The joint use has not yet been properly tested. Both solutions have been used with the same case ecosystem, but proper joint use requires further improvements in the designs of the solutions.

## 5.3 Limitations and future research

The main limitation of this thesis is related to the DSR process and its length. DSR processes often take a long time as the designed artefacts must be tested and proven in multiple contexts. The artefacts created in the scope of this thesis are initially tested and proven in one or few contexts but the work towards generalisation continues. The process for Ecosystem Profile creation and EcoGame have both been tested in the same context originating in the forestry industry. Additionally, variations of EcoGame have been used in research projects to study the dynamic nature of multilateral relationships in an emerging business ecosystem. The results from those games were valuable for the research projects as they also worked as basis for profitability analyses for the focal actors of the emerging ecosystem. The testing of EcoGame has therefore been initiated in multiple contexts and the game has been proven to be valuable, but currently the design of EcoGame requires a large amount of work when changing the context in the game. At the end of the current DSR process, both artefacts would be fully working solutions that can be used generally without modifying their design. In joint use, Ecosystem Profile creation would be automatic with Ecosystem Profiler, and the created profile could be implemented in EcoGame without additional work.

Another limitation relates to the thesis discussing collaboration and management at the upper level. For example, collaboration can be broken down to the elements of trust, commitment, communication, and even further. Each element of collaboration would bring depth to the understanding of the dynamic nature of the business ecosystem, but they would also complicate the overall study of the system. EcoGame is meant to be played in a session that lasts a few hours at most. If the game is made more complex to include further elements in its design, it would possibly prolong the preparation phase and hinder the entertainment aspect of playing a serious game. Studying different elements of collaboration with EcoGame can be done by analysing the gathered data about player behaviour with relevant methods instead of directly including the elements in the game design. This could be done without making the players aware of what the specific targets of analysis are and thus maintaining the game as easier to access for the players. Overall, the goals of Ecosystem Profiler and EcoGame should be clear for the practitioners using them but they should offer possibilities for much deeper analyses in research.

Future research in regards to the current DSR process is evident. The design processes for each solution need to be finished: for EcoGame through extended field testing with actors from real ecosystems, and for Ecosystem Profiler, the creation of the software solution to conduct the created profiling process. Ecosystem Profiler then needs to be tested by profiling real ecosystems and evaluating the accuracy of the profiles. When both solution artefacts are validated individually, the process of joint use will be tested. This process can be a new artefact in the current DSR process if necessary. The DSR process is concluded when both solutions individually and their joint use are validated.

Outside the current DSR process, the current solutions offer possibilities for future research to delve deeper into the business ecosystem strategies of different actors and how they affect the nature of business ecosystems. Currently ecosystem strategies are considered to be derivative from the strategies of the focal actors. Whether it requires a change in the ecosystem thinking of the ecosystem actors or us who study them, the strategic management of an ecosystem can be quite different in the future from what is currently understood. For example, we could see costs and finances managed on an ecosystem level to further optimise performance. The further alignment of the business ecosystem could lead to new niche players purely providing value towards tasks related to ecosystem management. With solutions like Ecosystem Profiler and EcoGame, different scenarios and potential developments of ecosystems can be simulated for further studies into what changes could be viable and performance enhancing.

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# Publication I

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# Serious Games for Decision-Making Processes: A Systematic Literature Review

Matti Rissanen(✉), Lasse Metso, Kalle Elfvengren, and Tiina Sinkkonen

Industrial Engineering and Management, Lappeenranta-Lahti University of Technology, Lappeenra, Finland
{matti.rissanen,lasse.metso,kalle.elfvengren, tiina.sinkkonen}@lut.fi

**Abstract.** In asset management one key element is the availability of information at right time for decision-making. Decision-making processes in organizations are often multi-actor problems. Studies to train and improve decision-making with serious games have been previously conducted. The term "serious game" describes an intention of the player or the developer of the game to include a purpose other than pure entertainment into the game. Serious games communicate their purpose to the player through immersive and fun gameplay. While being engaged in gameplay, the players are knowingly or subconsciously more receptive to learning and skill acquisition. The number of articles about serious games in decision-making has increased during recent years. In this study, a systematic literature review is performed by using the Scopus database. The purpose of the paper is to categorize and analyse the content of existing literature of serious games for decision-making processes in organizations. The paper also raises some points on what the current games lack considering organizational and technological trends.

**Keywords:** Serious games · Decision-making · Decision support · Simulation games

## 1 Introduction

Physical asset management can be seen as a process of identification, design, construction, operation and maintenance of assets. Management of critical assets requires reliable information for the decision-making process. (Faiz and Edirisinghe 2009) Better decision-making can be done by using better and more efficient information management (Vanier 2001). Serious games and games for learning in general are mostly used for knowledge acquisition but they have been successfully used also for example for skill acquisition and behavior change (Boyle et al. 2016).

Serious games are an approach for incorporating learning or training purpose in a fun and engaging game. Zyda (2005) defines a serious game as a mental contest where through entertaining gameplay the players' achieve a learning purpose built into the game. Playing any kind of a game is based on making series of decisions in the environment of the game. Abt (1970) mentions that testing different choices of


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decisions is too expensive and risky in many industrial and governmental settings due to complexity and incomplete information and serious games provide a way to compare alternatives. With serious games, complex decision-making processes can be simulated, trained and improved.

Conducting a preliminary literature review to support the design of a collaborative serious game for supporting inter-organizational decision-making processes in business ecosystems proved to be difficult. This systematic literature review investigates how serious games are used to support decision-making processes in organizations and aims to either support further research in the field of serious games in inter-organizational collaboration between companies or to reveal a gap in academic literature regarding such games.

In the Scopus database, over 200 papers can be found about supporting decision-making with a serious game between the years 2003 and 2017. A general conclusion after reviewing the large number of articles is that serious games are relevant for educational purposes as well as training decision-making in organizations. Serious games offer a possibility to learn and test complex decision-making situations in many different fields by simulating decision processes and studying the data of users' interactions. This literature review excludes serious game research concentrating purely on educational purposes because there is previous research on these topics with various other terms such as educational games or game-based learning.

## 2 Research Design

Scopus database was used to search with string "*TITLE-ABS-KEY ((“serious game” AND “decision making”) AND NOT (“education” AND NOT “training” ))*". This produced 197 search results that were screened out down to a final sample for analysis. As serious game as a term is used to also describe games with a purely educational use, these articles were excluded from the search but separately processed. Other searches were conducted in Scopus, Google Scholar and Google search engine to get a wider understanding to the topic in hand. For example, including other game terms "simulation game", "video game" and "computer game" in the search increased the amount of results in Scopus to 926. The other game terms steered the results too far from the training of decision-making processes and therefore the presented search string was deemed suitable for the purpose of this research.

The 197 search results were first combed through on abstract level and 82 of them were excluded from the review due to not presenting a specific game or decision-making process in organizational context. The remaining 115 papers were skimmed through and 78 were removed with the same criteria as on abstract level including the removal of papers with target players being customers or patients of an organization instead of its employees, or not indicating its target players clearly. For example, a serious game dedicated to rehabilitating drug addicts might aim to improve the decision-making of the drug addict but does not directly affect the decision processes within the organization facilitating the game. Third and final screening removed 14 papers out of the remaining 37 based on the papers introducing a game too early in its concept phase for the purposes of this paper. The games too early in the concept phase would not communicate their target players or the decision-making processes included in the game and therefore making the categorizing of those papers impossible. Out of the 39 search results disregarded with the "*AND NOT ("education" AND NOT "training")*" part of the search string, 5 were skimmed through based on abstracts and one was chosen for the final sample. This search condition excluded papers dedicated to educational purposes but specifically included educational papers with a training purpose.

Qualitative content analysis focuses on meaning rather than quantification. Content analysis is a technique to identify reference models and to estimate parameters from textual data (Luna-Reyes and Andersen 2003). Content analysis is a systematic research method (Krippendorff et al. 1980; Downe-Wambolt 1992). Content analysis is used to analyse data, which is in textual form.

## 3 Findings

The usage of serious games to train tasks involving decision-making within organizations is gaining traction. Out of the 24 analysed papers, 17 were written during the past five years (2013–2017) and the rest between the years 2005 and 2012. The 24 papers presented 20 different serious games of which only 2 are non-digital and 18 playable with computers or mobile devices. The papers are numbered in coding by the games they present. SKYBOARD-game is presented in four papers (4a-d), D-CITE in three (7a-c) and Muller and van de Boer-Visschedijk (2017) introduces two games, BrainRun (16) and Casual Tactical Decision Game (17).

13 games have simulation as primary or secondary game genre and 7 have role play. Most primarily role playing games have simulation as a secondary genre. The distinction between simulation and role play comes from a player assuming a role, for example a physician, and playing according to the role. Simulation puts the player in the game as themselves and puts them through tasks that simulate ones from the real world. Simulation is a natural choice for training purposes as the player automatically makes the link between game and the purpose of the training in real life. Role play on the other hand is a genre that is used to better support the engagement and immersion to the game play, especially when the player does not practice exactly the presented task in reality. Other primary or secondary game genres recognized are quiz (3), action (1), adventure (1) and strategy (1). A quiz presents a series of questions the player answers and at the same time learns more about the topics included, action game involves fast paced situations that require swift decision-making, adventure involves different kinds of events in a game world, and strategy requires decision-making on a strategic level. All made categorizations are presented in Appendix 1.

The decision-making situations in the analysed serious games were compared with the four phases of rational decision-making: intelligence, design, choice and implementation (Turban et al. 2010). Most of the decision-making training in the analysed games belong to the design and choice phases. The design phase means that the decision-making processes under training involve inventing, developing and analysing different courses of action. In the choice phase, the player selects an action from the alternatives developed in the design phase. This is not surprising as most of the processes in the games present some form of vague emergency or critical situation, which require swift, stable and correct decision-making – for example medical complex surgery procedures or modelling decisions of a player during critical situation in supply chain management. In the intelligence phase, the player would search for conditions that require decision-making and in the implementation phase adapt the made decision. Occurrence of each phase within the analysed games is presented in Table 1. Most of the games require the player to act in more than one phase of rational decision-making.

**Table 1.** Occurrence of rational decision-making phases in analysed games.

| Intelligence | Design | Choice | Implementation |
|---|---|---|---|
| 4 | 16 | 14 | 4 |

7 of the 20 analysed games are primarily related to healthcare, 4 to military, 3 to managing a conflict situation and 6 to other including project management, airport management, infrastructure planning, sports and financial decision-making. The use of serious games in training of tasks in the design and choice phases of rational decision-making also reflects in the fact that 14 of the games are single player and 6 multiplayer. 17 of the games are intra-organizational and only 3 involve roles of players inter-organizationally. All three inter-organizational, two of which are board games, are collaborative games. Inter-organizational collaboration is key in future. Games recognized here reflect that poorly, especially since only one game supports inter-organizational training in digital form, which is much more accessible to play than physical board game.

The stage of the analysed game in the papers concentrates on prototype level. The scale is from a concept, a prototype, validated to released. A concept means the paper does not present any test results, only thoughts on the design of the game. A prototype includes a proper playable version of the game and a validated game has gone through tests within its intended target group or otherwise can draw reliable conclusions on achieving its purpose. A released game means that the game is commercially available. 4 papers present a concept, 13 a prototype, 5 a validated and 2 a released game.

Content analysis visualization was done by creating a word cloud using NVivo software (see Fig. 1). In the word cloud, word frequency from the 24 analysed papers was examined. The most used word was *game* (synonyms included) with 2419 times in the analysed papers. The size of text in the word cloud tells the frequency of the word, a bigger font meaning higher frequency. The next frequent words were: *learning* (1698), *making* (1607), *training* (1591), *design* (1456), *process* (1228), *work* (1170), *take* (1061), *results* (1060), *decision* (1021), *study* (993), *performance* (972), *playe*r (899), *control* (840), *management* (830), and *serious* (801). However, a word of interest, collaboration, was far from the most frequent (*collaborative* (307) and *cdm* (242)). The last word in list (100$^{th}$) was *interaction*.

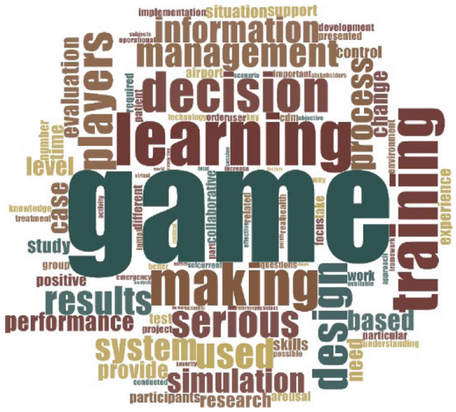


**Fig. 1.** Word cloud

## 4 Discussion and Conclusions

New and developing digital tools allow for better and more realistic simulations. Serious games including simulations in this study are still missing some elements, such as smell and feel. In "Auction Game" (Astor et al. 2013) biofeedback is used to give the player some of these missing elements but other games do not report similar usage. In addition, Anon (2010) notes that serious games do not provide stimulation for all senses using the lack of the smell of a battlefield as an example from their game.

The two most important findings were the lack of presence of the intelligence phase of the four phases of rational decision-making in the analysed games and the fact that the games concentrated on decision-making processes within a single organization. The intelligence phase includes determination of whether a problem requiring decision-making exists and the explicit definition of the possible problem. In the analysed papers, almost all of the presented games were already past this phase and the player knew the situation around which they had to make decisions. The lack of implementation phase is not as surprising since most of the games simulated this phase for the player after the player completed the choice phase. A quick glance at simulations used to optimize risk management procedures (e.g. a nuclear power plant, see Williamson et al. 2012) show that games to support the intelligence phase exist with other terminology (simulation game, simulation, gamification) than serious games, while fulfilling Zyda's (2005) definition of serious games–being entertaining and incorporating a learning purpose. Further research is required to connect the different terms to get a better understanding about using games with serious purpose to improve decision-making processes in organizations.

Inter-organizational decision process increases in complexity compared with one where the decision influences only a single organization. As Abt (1970) notes, complexity is one reason to use serious games to go through decision-making processes. However, only 3 out of the 20 analysed games involved inter-organizational decision-making. Here the further research directs towards designing and using serious games more in inter-organizational setting to test if they are indeed able to answer the issue of complexity of decision-making processes.

Decision-making in asset management requires relevant information for the basis for decisions. Serious games offer a tool for increasing the knowledge of the players about the topics they make decisions about in reality or develop the decision-making processes through simulation. Therefore, serious games are versatile in the way that they can both ensure the decision maker has the relevant information and is capable of making the decisions.

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## Appendix 1. Categorization of Serious Games for Decision-Making.

| Topic | Game platform | | Amount of players | | Training content for | | Game genre | | | | Subject of the game | | | | | Stage of the game (at the time of publication) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Digital | Non-digital | Single player | Multi player | Single organization | Inter-organizational | Simulation | RPG | Quiz | Other | Health care | Military | Conflict management | Airport management | Other | Concept | Prototype | Validated | Released |
| 1 | x | | x | | x | | | 1 | | | | | | | 1 | | | x | |
| 2 | x | | x | | x | | 1 | | | | 1 | | | | 2 | | | x | |
| 3 | x | | | x | x | | 1 | | | | | | | | 1 | x | | | |
| 4a | | x | | x | | x | 2 | 1 | | | | | | 1 | | x | | | |
| 4b | | x | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 4c | | x | | x | | x | 2 | 1 | | | | | | 1 | | | | x | |
| 4d | | x | | x | | x | 2 | 1 | | | | | | 1 | | x | | | |
| 5 | x | | | x | x | | 1 | | | | | 1 | | | | | | | x |
| 6 | x | | x | | x | | 2 | 1 | | | 2 | | 1 | | | | x | | |
| 7a | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 7b | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 7c | x | | | x | | x | 2 | 1 | | | | | | 1 | | | x | | |
| 8 | x | | x | | x | | | | 1 | | 1 | | | | | | x | | |
| 9 | x | | x | | x | | | | 1 | | | | | | 1 | | | x | |
| 10 | x | | x | | x | | 1 | | | | 1 | | | | | | | x | |
| 11 | | x | | x | | x | 2 | 1 | | | | | 1 | | | | x | | |
| 12 | x | | | x | x | | 1 | | | | 1 | | | | | | x | | |
| 13 | x | | x | | x | | 1 | | | | | | 1 | | | x | | | |
| 14 | x | | x | | x | | | 2 | | 1 | 1 | | | | | | x | | |
| 15 | x | | x | | x | | 2 | 1 | | | | | | | 1 | | x | | |
| 16 | x | | x | | x | | | | 1 | | | 1 | | | | | x | | |
| 17 | x | | x | | x | | | | | 1 | | 1 | | | | | x | | |
| 18 | x | | x | | x | | 1 | | | | 1 | | | | | | x | | |
| 19 | x | | x | | x | | 1 | | | | 1 | | | | | | x | | |
| 20 | x | | x | | x | | 1 | | | | | 1 | | | | | | | x |

1 = primary, 2 = secondary

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# Publication II

Ylönen, N., Rissanen, M., Ylä-Kujala, A., Sinkkonen, T., Marttonen-Arola, S., Baglee, D., and Kärri, T.
**A Web of Clues: Can Ecosystems Be Profiled Similarly to Criminals?**

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# A Web of Clues: Can Ecosystems be profiled similarly to Criminals?

**Ninni Ylönen [a], Matti Rissanen [a, *], Antti Ylä-Kujala [a], Tiina Sinkkonen [a], Salla Marttonen-Arola [b], David Baglee [b], Timo Kärri [a]**

[a] LUT University, Industrial Engineering and Management, P.O. Box 20, FI-53851 Lappeenranta, Finland

[b] University of Sunderland, Faculty of Technology, David Goldman Informatics Centre, St Peters Campus, Sunderland SR6 0DD, United Kingdom.

* Corresponding author at: LUT University, Industrial Engineering and Management, P.O. Box 20, FI-53851 Lappeenranta, Finland. Tel.: +358 50 573 8187

E-mail addresses: ninni.ylonen@hotmail.com, matti.rissanen@lut.fi, antti.yla-kujala@lut.fi, tiina.sinkkonen@lut.fi, salla.marttonenarola@gmail.com, david.baglee@sunderland.ac.uk, timo.karri@lut.fi

## Abstract

**The concept of an ecosystem has raised interest in many areas of research over the decades. There is a growing need to model and guide the operations, not just in single companies but also on ecosystem-level. To be able to do this, new and better tools are needed. This paper explores the ecosystems of organisations and presents the process for building an Ecosystem Profile. To understand ecosystems better, managers can utilise Ecosystem Profiles like criminal investigators utilise criminal profiles. Design Science Research is used to create the process, and the process steps utilise methods from web farming and Social Network Analysis. The created process is tested with an illustrative case. The process and the profiles created with it can be used by both researchers and managers. The Ecosystem Profile makes sense of the complex structure and gives data-based insights into the ecosystem under review.**

**Keywords**

Ecosystem Profile, Business Ecosystem, Profiling, Design Science Research, Web Farming, Social Network Analysis, Visualisation, Ecosystem Map, Ecosystem Management

# 1 Introduction

## *1.1 Background*

Nowadays, the competitive arena is composed of global ecosystems, so managers are forced to navigate through the constantly changing environment (Zahra and Nambisan, 2012). In order for companies to survive, grow and maintain competitive advantage in the future, they must systematically monitor and evaluate their business surroundings (Basole, 2014, p. 26). As time has passed and the business world has gone through significant changes, companies have realised that "they can't change the world alone" or, as Håkansson and Snehota (2006, p. 1) said, "no business is an island". For companies to thrive, they need others around them. Success will not happen in isolation.

When a solution for a customer need requires participation from multiple diverse actors, companies can no longer solely rely on their own abilities (Adner, 2006, p. 1; Iyer and Basole, 2016, p. 27; Moore, 2006, p. 32–33). Over the last decades, the concept of an 'ecosystem' has become an emerging phenomenon in many research areas (Adner, 2017; Böger and Lingens, 2019; Jacobides et. al, 2018). The concept of a business ecosystem was initially presented by Moore in 1993 (pp. 75–76). He defines the business ecosystem as "an economic community supported by a foundation of interacting organizations and individuals – the organism of the business world". Many other researchers have also explained the concept of a business ecosystem, each in a slightly different way (see e.g. Adner, 2017; Iansiti and Levien, 2004a; Wulf and Butel, 2017).

While competition between individual companies has shifted to competition between ecosystems, it is important to be able to study the ecosystems more thoroughly. “Ecosystems redefine the way organizations manage and govern their business” (Davidson et al., 2018, p. 26). Companies participating in ecosystems can ease access to new markets and customers. By understanding ecosystems, managers can improve their strategic decision-making (Davidson et al., 2018, p. 26; Iyer and Basole, 2016, p. 27). The ecosystem approach enables companies to analyse their own business and also the strength and success of their suppliers, partners and competitors (Mäkinen and Dedehayir, 2012, p. 208). At this time, there are not many ecosystems that have been fully researched and visualised. Business ecosystems are difficult to research and even more difficult to fully understand or describe. By profiling ecosystems, they can be observed and monitored better. Some known ecosystems, like Microsoft’s computing ecosystem and Wal-Mart’s retail ecosystem, have been examined (see e.g. Iansiti and Levien, 2004a, p. 83–105), but not many visualisations have been made. The profiling of ecosystems opens up new possibilities for research, supports managerial decision-making and as a result enables better understanding and management of ecosystems.

## *1.2 Objectives*

This study explores the ecosystems of organisations and the creation of an Ecosystem Profile. The purpose is to describe the components needed in an Ecosystem Profile and to illustrate the process by which an Ecosystem Profile can be created. Just like criminal investigators utilise criminal profiling as a tool to understand the motives and behaviour of a criminal (Kocsis, 2006a), the aim of Ecosystem Profiling is to be able to understand ecosystems more deeply. The connection between criminal intelligence and the analysis of networks in social sciences is recognised by Sparrow (1991). He notes that network analysis tools in social sciences during that time were designed for small and static networks rather than criminal networks he considers huge and dynamic (Sparrow, 1991, pp. 261–262). The connection is still relevant as small, static networks have transformed into huge and dynamic ecosystems, and therefore this study draws inspiration from a process of criminal profiling conducted by law enforcement (see Muller, 2000, pp. 239–240; Douglas et al., 1986, pp. 406–415). The methods and use of criminal profiling in law enforcement have evolved since Douglas et al. (1986) and are used in a variety of contexts, but the basic principles still hold to this day (McGuirk, 2019; Kocsis, 2015). The Ecosystem Profile aims to present the profile of a certain ecosystem by simulating its structure and relationships and creating company-specific profiles for the ecosystem actors.

To be able to construct a profile of any kind, the object of examination must be defined. Specifying the object of profiling gives a direction to the information to be collected. In criminal profiling, the object is the criminal who has committed a crime. Later on in this paper, this phase of determining the object of profiling is called *Ecosystem Core.* Ecosystem Core gives a starting point in the form of a value proposition and core companies for *Ecosystem Map* creation. The Ecosystem Map visualises the ecosystem under review. The Ecosystem Map widens the ecosystem view from the value proposition and core companies to other ecosystem actors. In a similar manner, the first three steps of criminal profiling (*Profiling inputs*, *Decision-process models*, *Crime assessment*) consist of gathering information about the crime scene, victims, potential suspects and other relevant factors. The crime is also reconstructed in the third step, like an Ecosystem Map visually reconstructs the structure of an ecosystem. The last three steps of the six-step criminal profile generation process are *Criminal profile*, *Investigation*, and *Apprehension* (Douglas et al., 1986, pp. 406–415). The connection between criminal and Ecosystem Profiling are further considered in Section 4 of this paper.

Without visualising the collected data, the Ecosystem Profile would simply be a file full of data without a perspective into the structure of the whole ecosystem. In the ecosystem, the focus is not on the dyadic relationships but rather on larger connections and sets of relations between actors. The Ecosystem Profile aims to give a visual representation of the complex relationships in an ecosystem, by illustrating the connections between ecosystem actors. *Ecosystem Information* is constructed after the actors and relations in the Ecosystem Map have been visualised. Without any additional information about the ecosystem actors, the Ecosystem Profile would just be a visual presentation of ecosystem relations. To understand the examined ecosystem and the actors in it more deeply, the profile must contain some information about the actors' industry, production, financial situation, company structure and so on. Ecosystem Information focuses on formatting the companies' 'basic situation' based on public information.

This paper continues with the relevant literature in Section 2. Section 3 presents the research design and used methodology. In Section 4, the created process for building an Ecosystem Profile is presented, and in Section 5 the process is tested with an illustrative case. Section 6 concludes the paper with discussion and conclusions.

## 2 Ecosystem of organisations

### *2.1 Concept*

The concept of a business ecosystem originates from the biological sciences (Moore, 1993; Mäkinen and Dedehayir, 2012, p. 207) and, over time, it has expanded into various fields. Nowadays researchers have recognised multiple ecosystem types. For example in 2010, Briscoe (pp. 39–43) defined the conceptual framework for a generic ecosystem from the definitions of a biological ecosystem, and utilised it to illustrate the varying ecosystems (e.g. digital ecosystem, social ecosystem, knowledge ecosystem and business ecosystem). Scaringella and Radziwon (2018) review the literature of ecosystem concepts starting from Moore (1993) to recognize differences and similarities between the different concepts. The business ecosystem offers a vision for actors of varying interests to join in for a common cause. It forms around a network of companies and individuals who provide a unique value proposition together.

Whereas networks are described by the ties between actors, ecosystems originate from a common value proposition (Adner, 2017, pp. 50–51). The members of a business ecosystem collectively create value for customers (Moore, 2006, p. 32–34; Mäkinen and Dedehayir, 2012, pp. 207–208; Kohtamäki and Rajala, 2016). Cluster, value network, strategic net and business ecosystems all interpret the business world in a slightly different way (Peltoniemi, 2004, p. 2; Möller and Halinen, 2017, pp. 9–13). Focusing only on companies in a particular cluster or value network might affect the ability to evolve and succeed. Unlike clusters, ecosystems are not limited to geographic locations, and the concept of an ecosystem refers to a much larger entity than the concept of a value network. A network can be a part of a broader ecosystem. Compared to a business ecosystem, when analysing organisation population, cluster and value networks present a more limited view of the dynamics and behaviour of such entities (Peltoniemi 2005, p. 59; Maglio and Spohrer, 2013, p. 669). This study focuses on the concept of a business ecosystem, as it best describes the dynamic structure of the business world.

Like species in biological ecosystems, the companies in the business world also interact with each other in a complex way. Companies are concurrently influenced by their internal capabilities as well as the complicated interactions with the rest of the ecosystem. In biological as well as business ecosystems, the actors are dependent on each other; the overall wellbeing and performance of each actor is dependent on the wellbeing and performance of the whole ecosystem (Iansiti and Levien, 2004a, p. 35). Collaboration in an ecosystem is not intended to restrict or prevent competition between companies. Competition in an ecosystem is a driving force of development, and sometimes one actor may be replaced to achieve cost savings or better effectiveness. In the business ecosystem, companies work collaboratively and competitively to support basic functions and to chase continuous innovation

(Moore, 1993, p. 76; Peltoniemi, 2005, p. 57). Co-creation can be seen as one of the most essential ecosystem characteristics. Being responsive to changes requires continuous realignment of knowledge, resources and talent (Basole et al., 2015, p. 2).

### *2.2 Structure*

According to Adner (2017, p. 43), ecosystems are constructed of four elements: activities (=actions to be undertaken), actors (=entities that undertake activities), positions (=actors' location in the system) and links (=transfers across actors), but in a simplified manner it can be said that ecosystems consist of nodes and connections. Iansiti and Levien (2002, p. 15) stated that there is a recurring 'formula' when thinking of ecosystem structure: "a small number of nodes in the network are much more richly connected than the vast majority of the members of the (eco)system". New, small or highly specialised companies are often working with fewer suppliers and partners compared to the companies in key roles in providing the value proposition.

According to Moore (1996, p. 26–27), the ecosystem forms around the core company. The ecosystem consists of layers, and the different layers are differently committed to the core company. The core forms the heart of the business, and it may consist of a single company coordinating the supply chain or several companies in a networked group. The second layer is called the extended enterprise. This layer widens the business view and includes customers, complementors, second layer suppliers and standard bodies. The outer layer of the ecosystem consists of companies that might not be directly involved in the core company operations, but might still have a significant effect on the survival and success of the business (Heikkilä and Kuivaniemi, 2012, p. 19–20; Moore, 1996).

Adner's (2017) perception extends Moore's view. Adner defined the ecosystem concept around the focal value proposition instead of the focal company. He divides the term ecosystem into two general views: ecosystem-as-affiliation, which focuses on actors, and ecosystem-as-structure, which is focused on activities. Considering these two approaches, they follow the opposite directions in strategic construction: the affiliation approach begins with the actors, continues by considering the links between the actors, and ends with the possible value proposition. In turn, the structure approach begins with the value proposition. Although the approaches are conceptually different, they are mutually consistent. In a certain situation, features from both approaches might be appropriate to utilise (Adner, 2017, p. 40–43).

### *2.3 Roles and relationships*

Being able to stay successful requires understanding of the ecosystem and the company's role in it. The role a company chooses to play must reflect the company's current state or future goals (Iansiti and Levien, 2004b, p. 74). A 'role' can be described as a "characteristic set of behaviours or activities undertaken by ecosystem actors" (Dedehayir et al., 2018, p. 18). Researchers have identified different roles in the ecosystems (see e.g. Dedehayir et al., 2018, p. 22–25; Davidson et al., 2018, p. 29), but probably the best known definition of ecosystem roles is presented by Iansiti and Levien (2004a, p. 68). According to their perception, ecosystem members can be separated into keystones, dominators and niche players.

Keystone companies have a great impact on the overall health of the ecosystem and its members. Even though keystones only represent a small part of the ecosystem, success or failure can be determined by them. Keystones utilise their central position in the ecosystem to create and share value with its ecosystem. They offer services, tools and technologies for other ecosystem members to utilise (Clarysse et al., 2014, p. 1166; Iansiti and Levien, 2004a, p. 68–72; Moore, 1993; Mäkinen and Dedehayir, 2012, p. 209). There are two factors separating dominators from keystones: physical size or abundance and the ability to encourage diversity. Unlike keystones, dominators occupy a big part of the nodes in the ecosystem. Dominators eliminate competitive companies by taking over their functions or by completely eliminating the whole business. Dominated ecosystems can be unstable and vulnerable because they do not have the diversity to respond to changes.

Even with dominators, companies can have relationships that are collaborative as well as competitive. This leads to co-opetition among ecosystem members (Mäkinen and Dedehayir, 2012, p. 210). The majority of ecosystem members follow niche strategies. Even though niche companies individually do not significantly affect other ecosystem members, they form the bulk of the ecosystem. Niche companies focus on developing specialised capabilities that differentiate them from the other ecosystem members. Niche companies utilise the services, tools and technologies of keystones to enhance their expertise (Iansiti and Levien, 2004a, pp. 72, 76–77).

## *2.4 Visualisation*

Ecosystems are complex systems that affect and are affected by various actors (Iyer and Basole, 2016, p. 27). Because of the dynamic nature of an ecosystem and its complex structure, drawing precise boundaries for an ecosystem is impossible (Iansiti and Levien, 2004b, p. 71). Ecosystem visualisations can be utilised in several ways: to map relationships between stakeholders, to analyse business issues, to structure a specific industry, or to explore new key actors (Basole et al., 2015, p. 5; Iyer and Basole, 2016, p. 27). The created graphics can be used to highlight the desired parts or features of the ecosystem. By being able to identify some key features, the development of an ecosystem can be guided towards a goal (Conway, 2014, pp. 108–111). Visualisation moves beyond traditional business reports and indicators. Visualisation provides a method for improved communication, makes data more accessible and enables decision-makers to process data, see patterns, spot trends and identify deviation (Basole, 2014, p. 26). The goal is not to eliminate human insight and foresight, but rather make it easier to interpret (Basole et al., 2015, p. 11). Typically, the visualisation of a business ecosystem is utilised among different analysts and experts, companies' decision-makers, venture capitalists, investors and management researchers (Basole et al., 2016, p. 272).

The increasing amount of digital data enables experts to analyse business ecosystems more thoroughly than before. However, even though the information itself might be valuable, its enormous amount limits its value. The validity of an ecosystem analysis depends on the nature and quality of the used data (Basole et al., 2015, pp. 4–5; Gauch et al., 2007, p. 54). When working with ecosystems, the quantity of data can become a problem. Multiple companies can be connected to multiple other companies. When there is almost an endless amount of information available, the collection of ecosystem data can quickly become unmanageable (Conway, 2014, pp. 105, 113; Jaspersen and Stein, 2019, p. 760).

Setting up some boundaries for the research is necessary. The struggle lies in trying to distinguish the major outlines and important links from those that are not so important (Levine, 1972, p. 14). For this reason, there are challenges in determining how many subsequent levels of nodes should be included in the visualisation: should there only be nodes that are directly connected to the central node or should there be nodes that are connected by an x number of steps? If the selected x is rather small, some interesting linkages may remain hidden, but if it is large, irrelevant nodes might be included (Basole et al., 2015, p. 7; Conway, 2014, p. 105).

# 3 Research design

## *3.1 Research approach*

Design Science Research (DSR) is based on the thought that if something is not quite right with the world, it needs to be changed (Johannesson and Perjons, 2014, p. 7). DSR studies existing artefacts and develops new ones, with the goal of solving practical problems people experience (van Aken, 2004, p. 225). The artefacts can be described as human-made objects used as solutions to practical problems (Johannesson and Perjons, 2014, p.7). Hevner (2007, p. 88) presents the three cycles of DSR that must be presented and clearly identified when doing a DSR project. The relevance cycle connects the contextual environment of the research project and the rigor cycle of the knowledge base to the design science activities. The design cycle utilises data and information from the previously described cycles. The design cycle builds and evaluates the design artefacts and the processes of the research (Hevner, 2007, pp. 88–91).

This study uses DSR for researching the ecosystems of organisations and creating the process for building an Ecosystem Profile. Ecosystem Profiling tries to tackle the problem of companies not necessarily understanding the ecosystems they take part in. The lack of understanding leads to a lack of management. In this study, the design artefact is the created process for the construction of an Ecosystem Profile. The usability of the process is tested by creating an Ecosystem Profile of an illustrative case. The illustrative case is presented in Section 5 of this paper.

### *3.2 Methods and data collection*

Figure 1 presents the research approach, methods and test utilised in this study. DSR has been utilised as an approach for the research. Social Network Analysis as well as Web Farming are methods that have been used to accomplish the set research objectives. These methods were used alternately when the Ecosystem Profile was built. The created process (design artefact) was tested with an illustrative case.

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|---|---|---|---|
| Research Approach | Design Science Research | | |
| | Used Methods | Social Network Analysis<br>Web Farming | |
| | | Creation of the Artefact | Illustrative case |

**Figure 1**. Approach, methods and test utilised in the research

Richard Hackathorn (1999) proposed a methodology called web farming. Web farming means “acquiring business-related information from the web, maintaining it and turning it into useful and actionable knowledge” (Masand and Spiliopoulou, 2000, p. 1). Lin et al. (2020, p. 1771) consider the purpose of web farming to be to actively gather data and continuously evolve the process of gathering data. In practice, in this research the first action towards farming the web for information about a new company or relationship was to conduct a web search with Google search engine. The linkages found from the webpages of a company could lead directly to new webpages to farm or lead to new web searches to be conducted. This study also utilises principles from Social Network Analysis (SNA) to visualise the connections in an ecosystem. SNA is a set of methods that can be used to explore and analyse social structures, especially the relation aspect (Scott, 2000, p. 38), by combining qualitative and quantitative data (Tóth et al., 2018; Badi et al., 2017). There are software tools developed for the purpose of conducting SNA (Memon et al., 2011, p. 55; Leenders et al., 2007, p. 465), but our work was done manually instead as the focus is not on analysis but rather on designing and testing a process. See Sapountzi and Psannis (2018, pp. 899–901) for a review of the five software tools to conduct SNA.

The following features are distinguished for SNA: emphasis on structuralism – focus on the relations within and between the actors; basis on empirical data – systematic collection and analysis; and the use of graphical images as part of its tools. SNA aims to visualise and explain social phenomena by exploring particular entities (e.g. people) and their interconnectedness in systems (Carolan, 2014, pp.

26, 44). Ranking the entities is also important to be able to see which are more important than others (Alguliev et al., 2012, p. 68). Even though SNA is primarily concerned with the relation aspect, in some cases it can be important to take into account the attributes of the entities as well (Alguliev et al., 2012, p. 65). SNA can be used to reveal complex patterns in the studied networks, but the results can also be difficult to analyse as the complexity of relations increases (Swan et al., 2007; Steiny and Oinas-Kukkonen, 2007). Social networks consist of actors, links and flows. The networks are constructed by identifying and connecting individual dyads (Conway, 2014, pp. 104, 106–108).

Generating visual material and collecting relational ecosystem data often happens in four stages (Jaspersen and Stein, 2019, p. 752). This study utilises a four-step process for ecosystem visualisation presented by Iyer and Basole (2016, p. 28):

1) determine industry structure,

2) identify companies and their attributes,

3) finalise semantics for nodes and dependencies,

4) visualise, analyse and interpret.

The first step means identifying the value chain or activities that deliver benefits to customers in a certain (chosen) industry. This is done by inferring the information from industry publications and company websites. The second step begins with defining the keystone company. After that, the following task is to look up actors providing services or components to the keystone and to identify dependencies. Most company websites list at least some information about their partners, suppliers, strategic alliances or relationship types (for example R&D, marketing, licensing). The third step aims to define how the different actors and dependencies will be presented (Iyer and Basole, 2016, p. 28). Most often the nodes represent companies, and lines represent connections between the companies. At this point, many specifications can be made to make the visual representation more informative and understandable (Jaspersen and Stein, 2019, p. 752). This will be achieved using visual variables such as size, colour and shape to describe individual actors and links. ‘Size’ is most often used to highlight quantitative features. ‘Colour’ and ‘shape’ are suited to describe qualitative features (Conway, 2014, p.111). The purpose of the fourth step is to visualise, analyse and interpret the collected data. The iterative process improves the quality of visualisation, so feedback from the companies in the ecosystems is valuable (Iyer and Basole, 2016, p. 28).

The illustrative case (presented in Section 5) was created by only using information available from public sources. Company webpages, publications and the Amadeus database (see Appendix I for full list and references) were used in the web farming process of collecting data for the illustrative case. The web farming was done manually as the purpose was to test the design artefact, the process of building an Ecosystem Profile, not the effectiveness of it. As most of the companies discussed in the illustrative case are Finnish, almost all the references found through web farming (Appendix I) and utilised in building the illustrative case are in Finnish.

## 4 The process of building an Ecosystem Profile

Profiling has been utilised in many different fields: for example targeted marketing and criminal and geographic profiling (Brusilovsky and Millán, 2007; Kocsis, 2006b; Young et al., 2011). An Ecosystem Profile aims to illustrate the ecosystem under review. By reflecting the principles of criminal profiling onto Ecosystem Profiling (see e.g. Kocsis 2006b, 2006a, p. 8), the intention is to characterise the ecosystem information and to define and describe the companies in the ecosystem. Figure 2 connects the steps of criminal profiling (see Douglas et al., 1986, pp. 406–415 for detailed descriptions of each step) to the phases of the process of building an Ecosystem Profile. The process of Ecosystem Profile creation is presented in Figure 3. The Ecosystem Profile should be viewed as a resource that can assist in analysing ecosystems, not as a “complete solution” for ecosystem analysis.

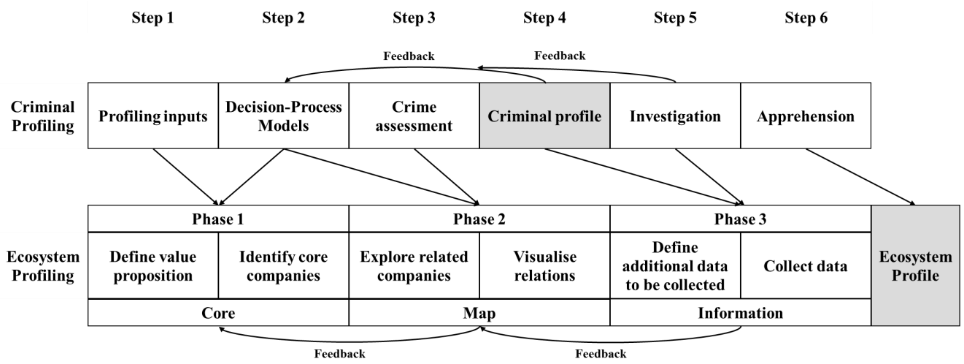


**Figure 2**. Steps of criminal and Ecosystem Profiling and the connection between the two.

The criminal profiling process goes on to use the criminal profile built in step 4 to investigate and apprehend the criminal. The Ecosystem Profile creation process (see Figure 3) investigates the actors of the ecosystem based on the Map created in phase 2. In criminal profiling, the *investigation* step can reveal new evidence or fail to identify a suspect (Douglas et al., 1986, p. 415) and previous steps must be revisited in the profiling process. Similarly, if phase 3 of Ecosystem Profiling reveals new 'evidence', the previous phases must be revisited before finalising the Ecosystem Profile. The *apprehension* step of criminal profiling would be the next step of using the finalised Ecosystem Profile in research or management. In this paper, we test the process of building an Ecosystem Profile but will not use it to achieve any further goals.

The construction of an Ecosystem Profile requires definition of the value proposition, identification of core companies, mapping of complex relationships and collection of company-specific data. The phases of the profile construction process are named according to the requirements presented above as *Core*, *Map* and *Information*. Figure 3 illustrates the three-phase, six-step process of Ecosystem Profile construction.

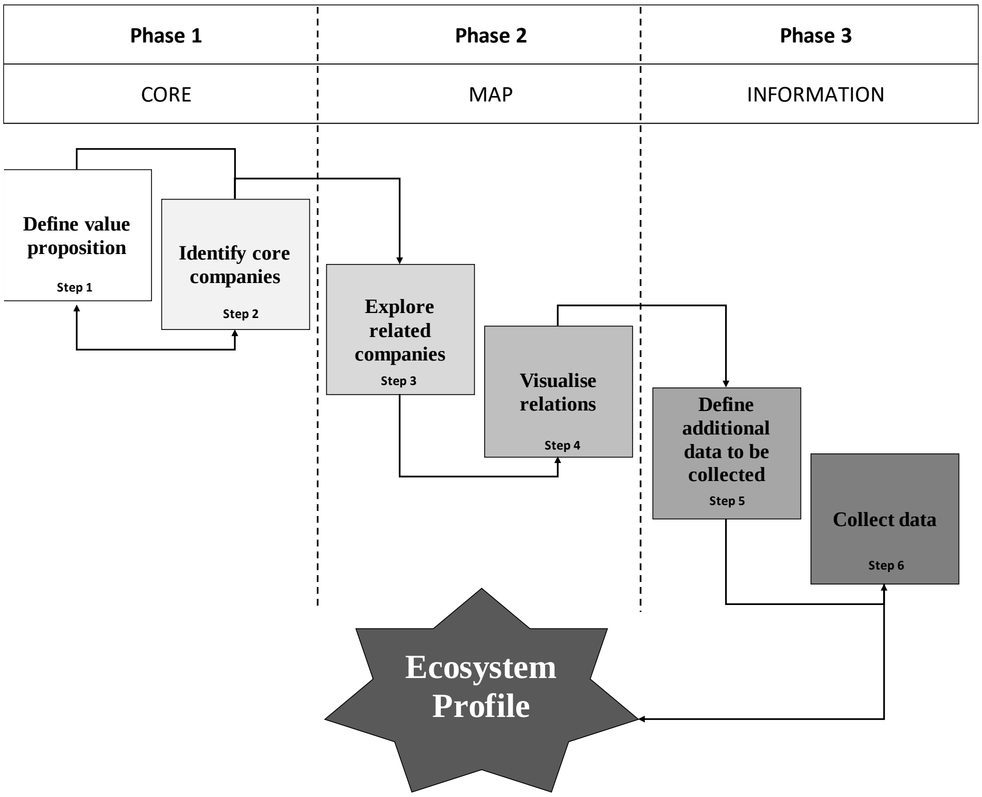


**Figure 3**. Process of Ecosystem Profile creation

In the first two phases, the aim is to create a picture of the ecosystem structure. This means exploring and mapping the connections between companies and finding the key relations using principles and tools from both web farming and SNA. These phases correspond well to the first three steps of criminal profiling where, for example, the crime scene, victim(s), forensics and the motive of the criminal are gathered. In addition, the crime is reconstructed like we reconstruct the profiled ecosystem as a visual map. The first two phases utilise the four-step process of ecosystem visualisation created by Iyer and Basole (2016, p. 28). A few of the steps have been modified for this research. The first step, determining the industry structure, is contradictory when talking about ecosystems. Therefore, this research focuses on identifying the core companies rather than identifying a specific industry. In the fourth step of Iyer and Basole's process, the collected data is visualised, analysed and interpreted. In this research, the focus is only on visualisation. In the third phase of Ecosystem Profile creation, the company-specific profiles are built. The company profiles can, for example, contain information about the company's business area, industry, financial situation and company structure.

The process utilises both Moore's (1996, p. 26–27) and Adner's (2017) ecosystem approaches. Visualisation utilises Moore's layered ecosystem view. Adner's ecosystem-as-structure approach begins with a value proposition and aims to identify the actors needed for the proposition to take place. This approach was utilised at the beginning of the process, where ecosystem actors were searched according to the defined value proposition. However, as presented in Figure 3, the first two steps can be done in either order depending on the ecosystem to be profiled. The ecosystem-as-affiliation approach emphasising actors and their dependencies was utilised in the process, when the focus was on finding and mapping ecosystem actors. Building the profile is an iterative process where the 'view of the ecosystem' gradually keeps getting more detailed. And like in criminal profiling, if new evidence is revealed during the later steps of the process, the earlier steps can be revisited (see feedback loop in Figure 2). At the beginning of the process, the view of the ecosystem is quite narrow and even imprecise, because the focus is only on finding some of the ecosystem actors. Later, as the ecosystem and its actors are examined more and the most important relations are found, the view of the ecosystem gets more accurate.

## 5 Illustrative case: Forestry machine fleet management

### *5.1 Ecosystem Core*

Defining the *Ecosystem Core* reflects the first step in criminal profiling where criminal investigators for example collect the key evidence and recognise the victim(s) of the crime. The aim is to form an initial guess of the research direction. The web farming process for our illustrative case began with the first step *define value proposition*. The value proposition of ‘fleet management for forestry machines’ was chosen due to a need recognised in previous research projects. For example, in projects S4Fleet, ReFaMo and ProDi, the authors recognised the need for profiling a business ecosystem within the topics of maintenance and asset management. Forestry industry was one common example in all projects. Therefore, there is a need for the process of building profiles in future projects in the field.

The second step *identify core companies*, corresponds with the first (*determine industry structure)* and second steps (*identify companies and their attributes*) of the ecosystem visualisation process created by Iyer and Basole (2016, p. 28). The second step began with an initial web search of the value proposition, revealing that there are at least three different forestry machine manufacturers (John Deere, Komatsu, Ponsse) who provide systems and services to deliver the defined value proposition. Therefore, we can be certain that a forestry machine manufacturer is one of the core companies we are looking for. Out of the three manufacturers, any could have been chosen and very likely would have led to a different looking Ecosystem Profile. We chose Ponsse as it is a strong national company with global operations. In addition, most of the source material would be in the main authors’ native language for better access.

The second step continued with a search for other core companies beside the forestry machine manufacturer. Web searches were used to explore the actors. The name of the company being examined was added before the search word. The used search words were customer, supplier, references, and fleet management. When exploring the actors in the ‘fleet management for forestry machines’ ecosystem including Ponsse, it was possible to detect two more core companies: an IT service provider and a customer (i.e. forestry machine end user). As the machine manufacturer and first core company recognised, Ponsse is assumed to be in the role of a keystone company.

An IT service provider who has at some point been developing the fleet management system provided by Ponsse is Herman IT. They are assumed to be in the role of a dominator in this particular ecosystem since their work has been essential in providing the value proposition but they are replaceable by another dominator – assuming Ponsse owns the system currently. One customer of Ponsse's forestry machines is recognised as Veljekset Hokkanen, who provides logging services. Ponsse has more than 200 forest machine entrepreneurs as customers and, for this case, only one of the entrepreneurs was chosen to represent the forestry machine end user. Veljekset Hokkanen follows the role of niche player in using the system and likely providing feedback for further development. UPM Kymmene and Metsä Group are major players in the Finnish forest industry. In this particular ecosystem, they purchase logging services from Veljekset Hokkanen. Because of their major influence as customers of the customers of Ponsse, they can be seen as dominators. In accordance with Moore's 'layered ecosystem', Figure 4 presents the chain relations and illustrates the core companies of the ecosystem.

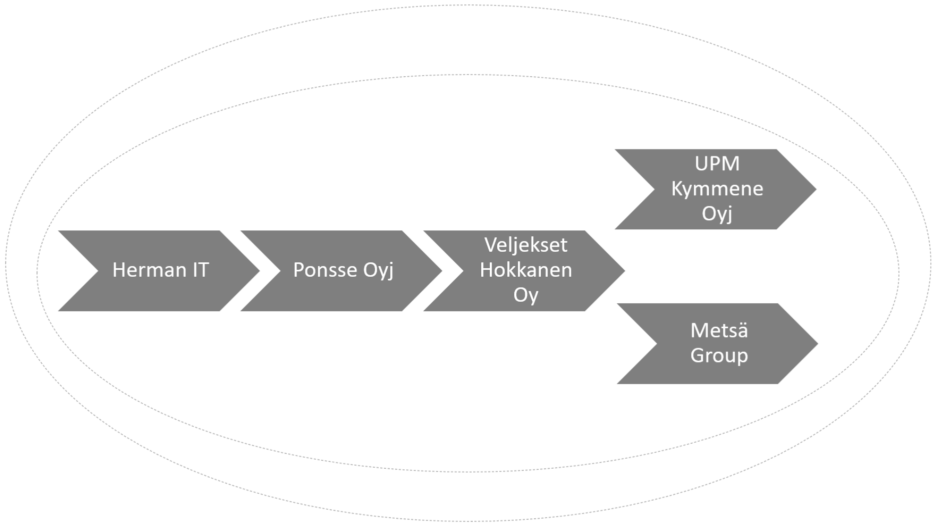


**Figure 4**. Core companies of a forestry machine fleet management ecosystem (Data gathered, Appendix I)

## *5.2 Ecosystem Map*

This section creates an 'Ecosystem Map' by visualising the connections between the ecosystem actors. The resulting Ecosystem Map is like the fourth, *Criminal Profile*, step of criminal profiling, where all the information from previous steps is connected and an actual profile with insight is built. In this illustrative case, an Ecosystem Map aims only to visualise the connections, so the nature or quality of the relationship is not relevant. The third step of the Profile creation process aims to e*xplore related companies*. After the core has been defined, the ecosystem view needs to be widened more. This was done by searching actors that have connections to the core companies. Again, web farming was used to collect the data. In addition to the search words presented before, the search words used in this step were business environment, collaboration, competitor, and management system. From the data, interesting linkages were found. For example, Epec is Ponsse's subsidiary and collaborates with Herman IT. Epec also has connections to Kesla, which is a competitor of Ponsse. Considering the relations of Epec, Kesla and Ponsse, Ponsse can possibly limit the services their competitor gets in regards to the value proposition. There can also be collaboration between these competitors that is not evident through public sources. This could be a sign of co-opetition within the ecosystem.

The fourth step, *visualise relations*, corresponds with steps three (finalising semantics for nodes and dependencies) and four (visualise, analyse and interpret) of Iyer and Basole's process. To make the map (Figure 5) informative and understandable, it was necessary to make some specifications. First and foremost, the nodes represent companies and the lines represent connections between the companies. Using different shades makes it easier to distinguish how the actors are connected. The core companies are coloured in black. Different shades of grey have been used to distinguish the customers, suppliers and other partners of each of the core companies. The extended enterprise is depicted on the outermost layer. The companies or other organisations in the outermost layer are Ponsse's competitors or other ecosystem actors, such as universities or research centres. The sizes of the nodes of the core companies correspond to their net sales volume: the bigger the node, the bigger the sales. The net sales may, to some extent, reflect the bargaining power between the companies. Figure 5 presents the Ecosystem Map for Ponsse's 'fleet management for forestry machines' ecosystem following Moore's (1996) vision of business ecosystem's visual presentation (see Section 2.2).

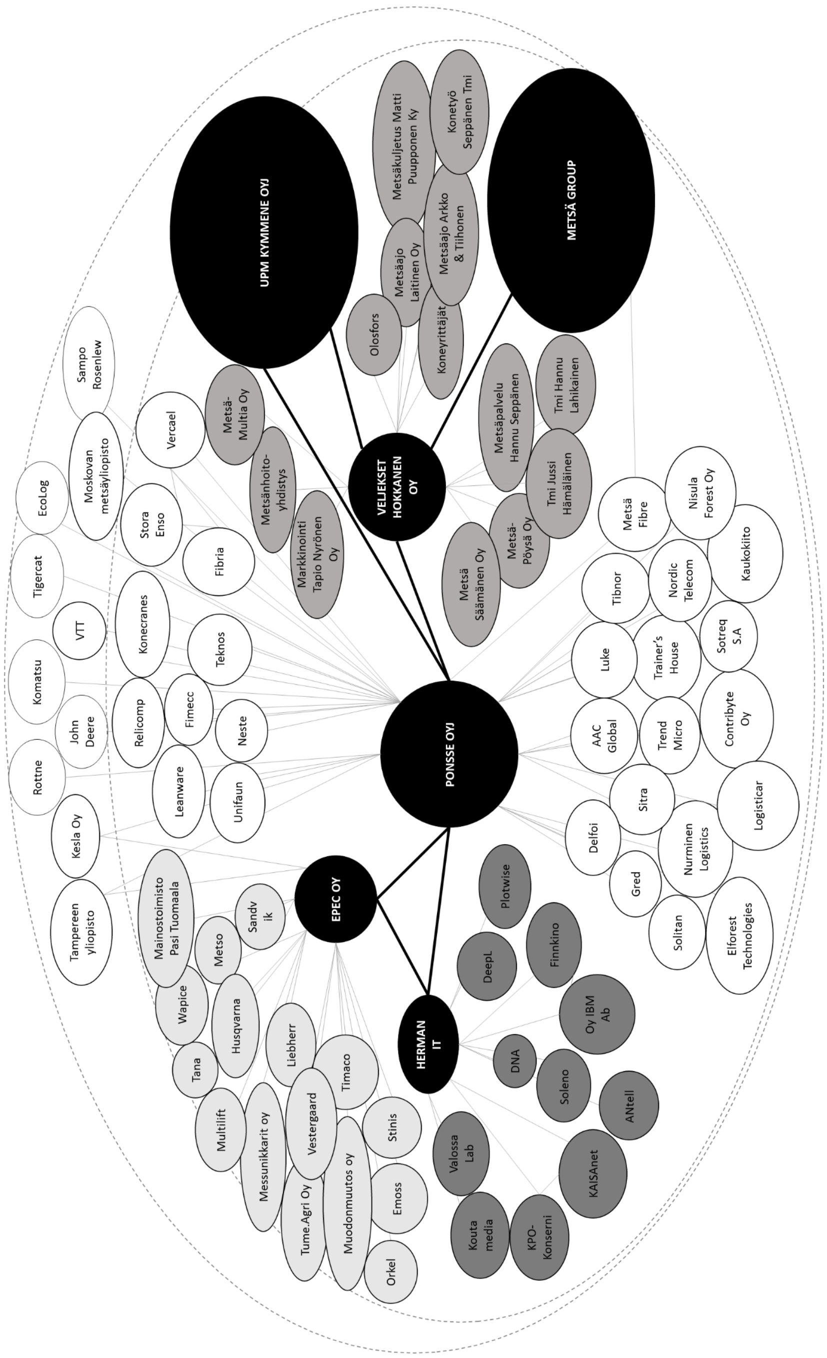


**Figure 5**. Ecosystem Map of Ponsse's 'fleet management for forestry machines' ecosystem (Data gathered, Appendix I)

## *5.3 Ecosystem Information*

The last phase of the process utilises the created Ecosystem Map. The idea is to add company-specific data to the Map to illustrate the Ecosystem Information. Step five of the process *defines the additional data to be collected.* Figure 6 shows how the company-specific profiles are created ‘on top’ of the previously created Ecosystem Map. It is possible to see that the data was divided into two parts: static information and dynamic information. This classification reflects user profiling, the purpose of which is to collect data from users, so it can be utilised in different settings (for example in targeted marketing). According to Mannens et al. (2013, p. 412), a user profile consists of three types of information: 1) static information, 2) dynamic information and 3) the social graph. The Ecosystem Map already comprises the social graph, so in this phase the aim is to collect static and dynamic information. Static information could contain information about the company’s products and services, company size, number of employees and financial situation. The dynamic information part would be focused on presenting what is said about the company. What does the company say about itself? The aim is to also be able to collect news, stock releases and other publications where the company is mentioned.

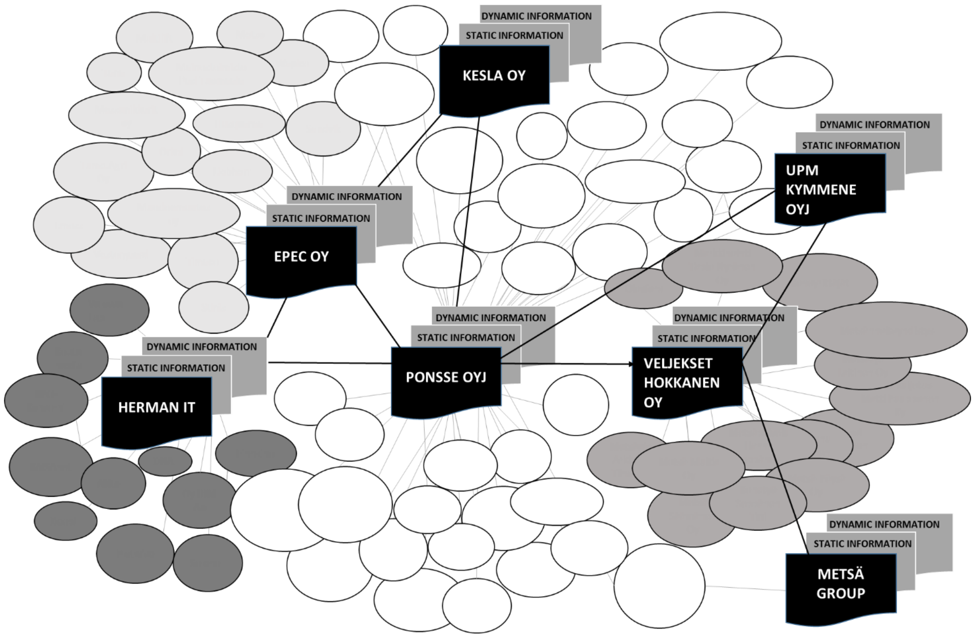


**Figure 6**. Illustration of **s**tatic and dynamic information in Ponsse's Fleet Management Ecosystem (Data gathered, Appendix I)

The final step of the process is to *collect the data*. The two final steps of Ecosystem Profiling create a more detailed understanding of the actors' current situation both as individuals and as actors of the ecosystem. It is an investigation into the actors of an ecosystem in a manner similar to the *investigation* step of criminal profiling. It is notable to remember that, although the intention is to create similar individual profiles for all the companies, it might not be possible. For this research, the financial data for each company was primarily extracted from the Amadeus database and some was collected through web farming as in the previous steps. Therefore, the quantity and quality of the data varies. Figure 7 provides an example of some of the information presented in a company profile. Appendix II presents the company profile view without the zoomed in boxes of information.

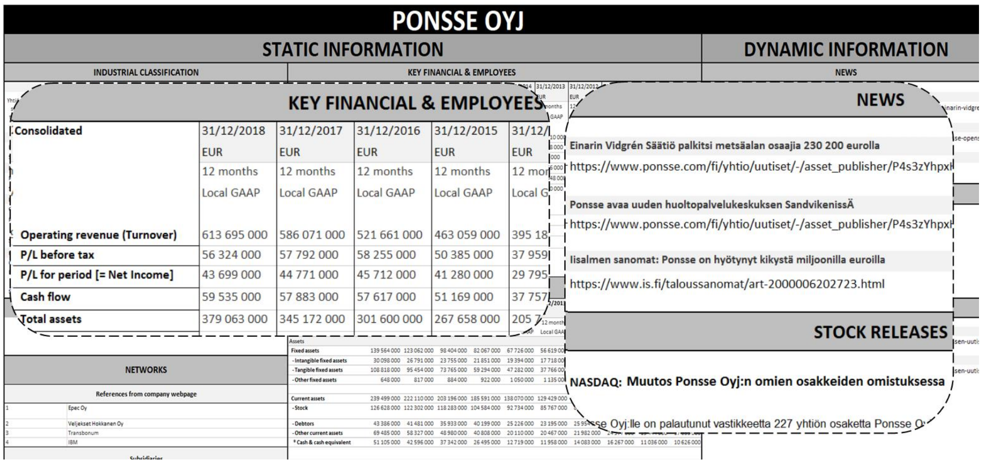


**Figure 7**. Examples of information presented in a company profile page inside an Ecosystem Profile (Data gathered, Appendix I)

# 6 Discussion and conclusions

## *6.1 Discussion*

Currently companies understand and manage the ecosystems they take part in poorly. There might not be enough knowledge to form relations with the most compatible companies in an existing or new ecosystem. The need to model and guide business operations, even on an ecosystem level, is growing, which means that new and better tools are needed. Ecosystem Profiling seeks to meet this growing need. An Ecosystem Profile simulates the structure and relationships of an ecosystem. It makes sense of the complex ecosystems and gives data-driven insights into the ecosystem under review. The profile can be utilised for many purposes in research as well as in management. As mentioned in Section 5.1, the authors have recognised the need for profiling ecosystems in past research projects, and therefore the process of creating an Ecosystem Profile is certainly utilised in future projects. The profile can be used as a tool to understand and manage ecosystems. Understanding ecosystems can help new companies evaluate the ecosystem they will be a part of and plan their business accordingly. Better understanding of ecosystems opens up new possibilities for activities that provide support for decision-making. It is possible that, in the future, companies will have business controllers that focus on ecosystem management.

Companies and connections that are not clear to all actors in the ecosystem can be detected. For example in our illustrative case, the connections found during the third step of profiling between Ponsse, Epec and Kesla were unexpected but, in retrospect, potentially a natural sign of co-opetition in an ecosystem. Profiling enables the identification or building of more complex research settings that go beyond the traditional organisational boundaries and dyadic relationships. Ecosystem Profiling can be used to better understand why something happened, did not happen or probably should happen in the future. Profiling enables the recognition of problems and targets for development within an ecosystem or helps to determine the compatibility of an existing ecosystem. It can help managers find suitable partners when needed or to spot unsuitable ones. Potential ecosystems could also be evaluated through profiling before they are even formed because, as noted by Shamsuzzoha et al. (2012, p. 379), it is necessary to identify your potential partners before engaging in collaboration.

If multiple ecosystems could be illustrated within a sensible time frame, their abilities, similarities and differences could be examined and analysed. This could enable some kinds of classifications of the ecosystem types. Such classifications could be used the way different industry classifications have been used. In the future, Ecosystem Profiling could also be utilised to follow the evolutionary development of an ecosystem. Ecosystems have relatively clear evolutionary stages, but recognising these and their transformation can be challenging. By being able to create graphs of the ecosystems in a systematic way, their development and changes could be more easily followed. However, it is important to note that the Ecosystem Profiles are static in the way that they present a situation at a certain point of time. The profiles can be made dynamic by updating them periodically and allowing new kinds of analyses to be made based on the development of the profiled ecosystems.

### *6.2 Conclusions*

This paper presented the creation of a six-step, three-phase process of building an Ecosystem Profile. The steps draw inspiration from the six-step criminal profile generating process by Douglas et al. (1986). The use of the process of building an Ecosystem Profile was illustrated with a case with a value proposition in ‘fleet management for forestry machines’. Even though the goal is not to investigate and apprehend a criminal suspect, Ecosystems can be profiled and investigated in a manner similar to criminals.

In terms of future research, Ecosystem Profiling opens up multiple new avenues. The *apprehension* of criminal profiling includes the validation of the profiling process. It is similarly necessary to determine objective criteria for the evaluation and validation of the Ecosystem Profiling process – how successful the process was and how useful and comprehensive the resulting profile was. Additionally, the resulting profile can be used to delve deeper into the relations within the ecosystem and as a basis for simulations on, for example, collaboration between multiple actors. The profile also opens up perspectives into the risk management of an ecosystem. A geographical, political or other disruption can cause sudden changes in an ecosystem and break critical relations. With Ecosystem Profiling, scenarios can be analysed and ecosystems be prepared for probable and improbable disruptions.

Like many other visualisation tools, the process of visualising the ecosystem requires a lot of manual work. Both the web farming and visualisation in this work were conducted manually. In the future, the aim is to create an Ecosystem Profiler tool that can automatically retrieve information from different sources and create profiles for ecosystems. By automating the construction of an Ecosystem Profile, time is freed up for making new observations and analysing the ecosystem more deeply. The presented illustrative case was created using web farming data from public sources. The time freed up through automation could be used for example for conducting interviews or surveys within the case ecosystem to gain further insight for the purposes of profiling, especially for the managerial uses of the profile. This could be unnecessary to maintain an objective perspective. It all depends on how the built profile is going to be utilised and at what type of *apprehension* the Ecosystem Profiling process ends.

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**Appendix II**. A company profile page within an Ecosystem Profile.

## STATIC INFOR

### INDUSTRIAL CLASSIFICATION

**Trade description (original language)**

Yhtiön toimialana on valmistaa, tuoda maahan ja edelleen markkinoida metsäkoneita, muita metallialan tuotteita sekä tietojärjestelmälaitteita ja -ohjelmistoja. Lisäksi yhtiön toimialana on koulutus- ja konsultaatio-palvelujen tuottaminen, hallintopalvelujen tuottaminen konserni-yhtiöille sekä vakuutusedustustoiminnan harjoittaminen. Lisäksi yhtiö voi omistaaja hallita arvopapereita ja kiinteistöjä sekä käydä niilläkauppaa.

| | | |
|---|---|---|
| **TOL 2008 code(s)** | | |
| Primary code : | 28300 | - Manufacture of agricultural and forestry machinery |
| Secondary code(s) : | 46610 | - Wholesale of agricultural machinery, equipment and supplies |
| **NACE Rev. 2 code(s)** | | |
| Primary code : | 2830 | - Manufacture of agricultural and forestry machinery |
| Secondary code(s) : | 4661 | - Wholesale of agricultural machinery, equipment and supplies |
| **NAICS 2017 code(s) {derived from NACE Rev.2 codes}** | | |
| Core code : | 3331 | - Agriculture, Construction, and Mining Machinery Manufacturing |
| Primary code : | 333111 | - Farm Machinery and Equipment Manufacturing |
| | 333112 | - Lawn and Garden Tractor and Home Lawn and Garden Equipment Manufacturing |
| Secondary code(s) : | 423820 | - Farm and Garden Machinery and Equipment Merchant Wholesalers |
| **US SIC code(s) {derived from NACE Rev.2 codes}** | | |
| Core code : | 352 | - Farm and garden machinery and equipment |
| Primary code : | 3523 | - Farm machinery and equipment |
| | 3524 | - Lawn and garden tractors and home lawn and garden equipment |
| Secondary code(s) : | 5083 | - Farm and garden machinery and equipment wholesale dealing in |

### MARKET SERVED

### NETWORKS

**References from company webpage**

| | |
|---|---|
| 1 | Epec Oy |
| 2 | Veljekset Hokkanen Oy |
| 3 | Transbonum |
| 4 | IBM |

| | |
|---|---|
| **Consolidated** | |
| Operating revenue (Turnover) | |
| P/L before tax | |
| P/L for period [= Net Income] | |
| Cash flow | |
| Total assets | |
| Shareholders funds | |
| Current ratio (x) | |
| Profit margin (%) | |
| ROE using P/L before tax (%) | |
| ROCE using P/L before tax (%) | |
| Solvency ratio (Asset based) (%) | |
| Number of employees | |

| |
|---|
| **Consolidated** |
| Assets |
| Fixed assets |
| - Intangible fixed assets |
| - Tangible fixed assets |
| - Other fixed assets |
| Current assets |
| - Stock |
| - Debtors |
| - Other current assets |
| * Cash & cash equivalent |

# PONSSE OYJ

## TIC INFORMATION

### KEY FINANCIAL & EMPLOYEES

| Consolidated | 31/12/2018 | 31/12/2017 | 31/12/2016 | 31/12/2015 | 31/12/2014 | 31/12/2013 | 31/12/2012 | 31/12/2011 | 31/12/2010 | 31/12/2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR |
| | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months |
| | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP |
| Operating revenue (Turnover) | 613 695 000 | 586 071 000 | 521 661 000 | 463 059 000 | 395 189 000 | 319 710 000 | 315 485 000 | 332 160 000 | 263 790 000 | 139 538 000 |
| P/L before tax | 56 324 000 | 57 792 000 | 58 255 000 | 50 385 000 | 37 959 000 | 14 248 000 | 20 513 000 | 26 046 000 | 24 448 000 | -15 550 000 |
| P/L for period [= Net Income] | 43 699 000 | 44 771 000 | 45 712 000 | 41 280 000 | 29 795 000 | 9 098 000 | 13 890 000 | 14 812 000 | 23 338 000 | -20 251 000 |
| Cash flow | 59 535 000 | 57 883 000 | 57 617 000 | 51 169 000 | 37 757 000 | 15 666 000 | 19 752 000 | 20 033 000 | 28 417 000 | -15 007 000 |
| Total assets | 379 063 000 | 345 172 000 | 301 600 000 | 267 658 000 | 205 796 000 | 186 048 000 | 181 732 000 | 173 932 000 | 161 704 000 | 144 262 000 |
| Shareholders funds | 200 155 000 | 176 846 000 | 149 796 000 | 117 912 000 | 86 016 000 | 67 550 000 | 81 444 000 | 78 563 000 | 75 166 000 | 61 612 000 |
| Current ratio (x) | 1,82 | 1,83 | 1,95 | 1,70 | 1,62 | 1,64 | 1,67 | 1,77 | 1,80 | 1,88 |
| Profit margin (%) | 9,18 | 9,86 | 11,17 | 10,88 | 9,61 | 4,46 | 6,50 | 7,84 | 9,27 | -11,14 |
| ROE using P/L before tax (%) | 28,14 | 32,68 | 38,89 | 42,73 | 44,13 | 21,09 | 25,19 | 33,15 | 32,53 | -25,24 |
| ROCE using P/L before tax (%) | 30,80 | 38,24 | 39,38 | 56,29 | 48,20 | 32,29 | 37,17 | 42,23 | 43,14 | 3,03 |
| Solvency ratio (Asset based) (%) | 52,80 | 51,23 | 49,67 | 44,05 | 41,80 | 36,31 | 44,82 | 45,17 | 46,48 | 42,71 |
| Number of employees | 1 635 | 1 508 | 1 435 | 1 329 | 1 200 | 1 027 | 994 | 948 | 825 | 858 |

### BALANCE SHEET

| Consolidated | 31/12/2018 | 31/12/2017 | 31/12/2016 | 31/12/2015 | 31/12/2014 | 31/12/2013 | 31/12/2012 | 31/12/2011 | 31/12/2010 | 31/12/2009 |
|---|---|---|---|---|---|---|---|---|---|---|
| | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR | EUR |
| | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months | 12 months |
| | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP | Local GAAP |
| Assets | | | | | | | | | | |
| Fixed assets | 139 564 000 | 123 062 000 | 98 404 000 | 82 067 000 | 67 726 000 | 56 619 000 | 52 160 000 | 40 067 000 | 36 187 000 | 36 000 000 |
| - Intangible fixed assets | 30 098 000 | 26 791 000 | 23 755 000 | 21 851 000 | 19 394 000 | 17 718 000 | 15 338 000 | 12 497 000 | 10 011 000 | 9 118 000 |
| - Tangible fixed assets | 108 818 000 | 95 454 000 | 73 765 000 | 59 294 000 | 47 282 000 | 37 766 000 | 35 525 000 | 26 165 000 | 24 441 000 | 24 982 000 |
| - Other fixed assets | 648 000 | 817 000 | 884 000 | 922 000 | 1 050 000 | 1 135 000 | 1 297 000 | 1 405 000 | 1 735 000 | 1 900 000 |
| Current assets | 239 499 000 | 222 110 000 | 203 196 000 | 185 591 000 | 138 070 000 | 129 429 000 | 129 572 000 | 133 865 000 | 125 517 000 | 108 262 000 |
| - Stock | 126 628 000 | 122 302 000 | 118 283 000 | 104 584 000 | 92 734 000 | 85 767 000 | 81 636 000 | 80 475 000 | 72 391 000 | 67 920 000 |
| - Debtors | 43 386 000 | 41 481 000 | 35 933 000 | 40 199 000 | 25 226 000 | 23 195 000 | 25 954 000 | 28 413 000 | 33 682 000 | 22 687 000 |
| - Other current assets | 69 485 000 | 58 327 000 | 48 980 000 | 40 808 000 | 20 110 000 | 20 467 000 | 21 982 000 | 24 977 000 | 19 444 000 | 17 655 000 |
| * Cash & cash equivalent | 51 105 000 | 42 596 000 | 37 342 000 | 26 495 000 | 12 719 000 | 11 958 000 | 14 083 000 | 16 267 000 | 11 036 000 | 10 626 000 |

# DYNAMIC INFORMATION

| | |
|---|---|
| 31/12/2010 | 31/12/2009 |
| EUR | EUR |
| 12 months | 12 months |
| Local GAAP | Local GAAP |
| 263 790 000 | 139 538 000 |
| 24 448 000 | -15 550 000 |
| 23 338 000 | -20 251 000 |
| 28 417 000 | -15 007 000 |
| 161 704 000 | 144 262 000 |
| 75 166 000 | 61 612 000 |
| 1,80 | 1,88 |
| 9,27 | -11,14 |
| 32,53 | -25,24 |
| 43,14 | 3,03 |
| 46,48 | 42,71 |
| 825 | 858 |

| | |
|---|---|
| 31/12/2010 | 31/12/2009 |
| EUR | EUR |
| 12 months | 12 months |
| Local GAAP | Local GAAP |
| 36 187 000 | 36 000 000 |
| 10 011 000 | 9 118 000 |
| 24 441 000 | 24 982 000 |
| 1 735 000 | 1 900 000 |
| 125 517 000 | 108 262 000 |
| 72 391 000 | 67 920 000 |
| 33 682 000 | 22 687 000 |
| 19 444 000 | 17 655 000 |
| 11 036 000 | 10 626 000 |

## NEWS

**Einarin Vidgrén Säätiö palkitsi metsäalan osaajia 230 200 eurolla**

https://www.ponsse.com/fi/yhtio/uutiset/-/asset_publisher/P4s3zYhpxHUQ/content/einarin-vidgren-saatio-

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## STOCK RELEASES

**NASDAQ: Muutos Ponsse Oyj:n omien osakkeiden omistuksessa**

Ponsse Oyj:lle on palautunut vastikkeetta 227 yhtiön osaketta Ponsse Oyj:n vuoden 2018 osakepohjaisen kannustinjärjestelmän ehtojen perusteella.

Palautuksen jälkeen Ponsse Oyj:llä on hallussaan 227 kappaletta omia osakkeitaan.

## OTHER PUBLICATIONS

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**Ponsse uutiskirje - kesä-heinäkuu 2019**

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# Publication III

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**Multilateral Collaboration in Ecosystems - Studying and Improving with EcoGame**

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# Multilateral collaboration in ecosystems – studying and improving with EcoGame

Matti Rissanen*

Lappeenranta-Lahti University of Technology,
P.O. Box 20, 53851 Lappeenranta, Finland
E-mail: matti.rissanen@lut.fi

Tiina Sinkkonen

Lappeenranta-Lahti University of Technology,
P.O. Box 20, 53851 Lappeenranta, Finland
E-mail: tiina.sinkkonen@lut.fi

Timo Kärri

Lappeenranta-Lahti University of Technology,
P.O. Box 20, 53851 Lappeenranta, Finland
E-mail: timo.karri@lut.fi

Antti Ylä-Kujala

Lappeenranta-Lahti University of Technology,
P.O. Box 20, 53851 Lappeenranta, Finland
E-mail: antti.yla-kujala@lut.fi

* Corresponding author

**Abstract:** Companies in innovation, business or other ecosystems seek benefits from multilateral collaboration but are not necessarily comfortable with sharing information the collaboration requires. This managerial problem is accompanied with the fact that our knowledge on multilateral collaboration in different ecosystems is lacking. Multilateral relationships and collaboration in them are complex systems that are difficult to study and manage with traditional research methods and managerial tools. Multilateral collaboration in ecosystems concretizes as co-innovation and co-creation activities. Serious games combine learning and entertainment and can be used for simulating real collaborative decision-making situations. This paper presents the design science research process of EcoGame. EcoGame has been tested in field to understand what kind of dynamics exist within the multilateral collaboration and what data can be collected. The data can then be used for improvement of the game, better managerial decisions and scientific research into the dynamics of multilateral relationships.

**Keywords:** serious game; data collection; design science research; multilateral relationship; business ecosystem; collaboration; research game; inter-organizational; information sharing

## 1 Introduction

To deliver value to end customers efficiently and being able to compete, companies must form collaborative relationships. This collaboration has long been in the form of bilateral relationships in, for example, supply chains. Global disruptions like economic crisis in 2008 and pandemic in 2020 cause sudden changes to both local and global competitive environments and require stronger collaboration structures than supply chains. For companies to thrive, they need to increase their collaboration and understanding of it beyond their traditional supply chains into multilateral relationships within business ecosystems.

Companies engaging in business ecosystems have common goals and to make collaborative decisions that yield the best benefits, they must share information of different levels of sensitivity. Companies are comfortable with sharing technical knowledge (Feller et al., 2009; Li et al., 2012) with their ecosystem partners, but are not ready to attempt to gain the further benefits through sharing sensitive, detailed cost or profitability information (Kajüter & Kulmala, 2005; Windolph & Möller, 2012; Sinkkonen et al., 2013). There is room for improvement in collaboration in business ecosystems and more understanding into the dynamics of collaboration in business ecosystems needs to be generated.

Simulation within games is a good method to study complex social systems, like business ecosystems, and the players' behavior and interactions in the simulated environment (Bekebrede & Mayer, 2006). A game presents its players decision making situations in a specific context around a specific theme and turns it into play. Games are known to be used purely for entertainment or for learning purposes (Garris et al., 2002), but serious games are an approach combining these two (Zyda, 2005; Dörner et al., 2016). Relationships within a business ecosystem are multilateral (Adner, 2017) and such relationships can be considered as complex social systems. When a serious game incorporates simulations of processes, the data gathered from the process of the game can be used to study the real process as well (Bekebrede & Mayer, 2006). This approach can help studying collaboration and decision making in business ecosystems where data from real processes is scarce or unavailable due to complexity, sensitivity and long time scale between observable events.

This research uses design science research approach to design a research artefact, a serious game called EcoGame, which simulates collaborative decision making processes and related collaboration (e.g. information sharing) in multilateral relationships of business ecosystems. EcoGame is designed for studying said relations and to improve collaborative decision making in them. Business ecosystems are complex systems and the dynamics within are difficult to study. Serious games to study and improve inter-organizational decision making are scarce (Rissanen et al., 2020) and therefore the design for EcoGame cannot be adopted from an existing design science research artefact.

The lack of information sharing is one big barrier in making informed collaborative decisions in multilateral relationships. Other barriers and risks related to collaboration in business ecosystems are also recognized in literature (Fawcett et al., 2007; Audy et al., 2010) and solutions to minimize or eliminate them are required. Therefore, it is important to study these relationships further and serious game as an approach allows the conduct of research and at the same time breaking of the barriers in practice. Figure 1 illustrates how EcoGame is positioned among serious games used for learning and conducting research on the perspectives of a single organization or ecosystems based on literature searches.

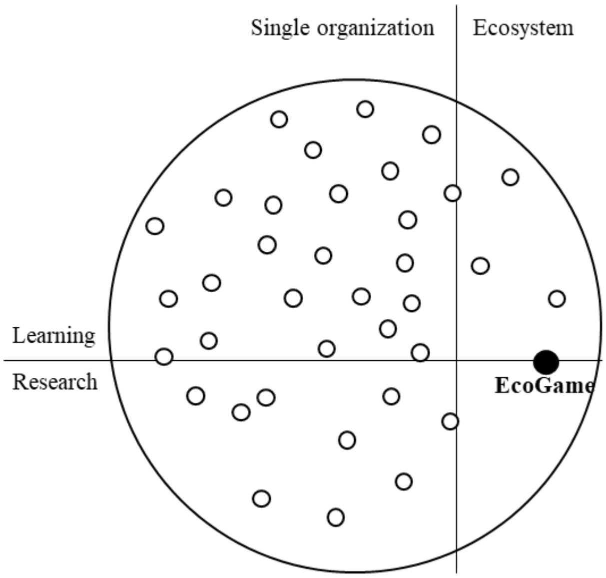


**Figure 1** Positioning EcoGame in the field of serious games used for learning and research in single organizations and ecosystems based on literature searches

This paper explores the design of EcoGame and its evolution through field tests. The field testing process and evolution of the game design provides data in various forms that can be used for research. The following research questions are explored:

1. How to design a serious game that simulates collaborative decision making in multilateral relationships of business ecosystems?
2. What types of qualitative and quantitative data for future research are generated from field tests of the serious game?

## 2 Background

### *From bilateral relationships to business ecosystems*

Moore (1993) suggests that a company is a part of a business ecosystem, which takes part in multiple industries. Much like a biological ecosystem, a business ecosystem forms naturally of companies and other stakeholders that together are able create more value to customers (Clarysse et al., 2014; Eisenhardt & Galunic, 2000; Moore, 1998). Defining the boundaries of a business ecosystem is impossible, since not all actors work directly with each other. Companies also establish new connections and break old ones frequently. Business ecosystem consists of multilateral relationships but an example of a networked structure consisting of bilateral relationships is a supply chain. The structures of supply chains are easier to define and collaborations within one can be broken down to collaboration between two actors. The positions of actors are however fixed in supply chains which causes them to be inflexible compared to business ecosystems (Adner, 2017).

Rather than attempting to look at a business ecosystem as whole, one should try to identify smaller groups of companies closest to each other, to draw conclusions on the functionality of the whole ecosystem (Iansiti & Levien, 2004). These smaller groups of companies form multilateral relationships that in the context of business ecosystems cannot be broken into bilateral ones. In addition to the structure of the ecosystem constantly changing, also the composition of individual decision makers changes.

By collaborating in a networked environment such as a business ecosystem, companies can lower their costs and improve their performance to achieve higher profits (Ramanathan & Gunasekaran, 2014; Audy et al., 2010). Organizations taking part in networked environments benefit from reach to new markets, complementary skills, sharing of resources and risk, and increase in actual or perceived size (Naylor, 2002). Open communication is required for every individual company in the ecosystem to gain additional benefits (Kulmala, 2002). Inter-organizational sharing of technical knowledge has been recognized as a way to reach higher profits than individually possible (Dyer & Singh, 1998) and to improve innovation within the companies (Hung et al., 2008; Feller et al., 2009; Du & Ai, 2008). However, Hallikas et al. (2004) recognize that sharing information in a networked environment causes additional uncertainty and risk because of the increased dependency between the actors. Fawcett et al. (2007) have observed four barriers for information sharing in inter-organizational relationships: cost and complexity of technologies, incompatibility of systems, connectivity issues within the supply chain, and lack of willingness to share. Audy et al. (2010) add a fifth barrier to the list – information security and confidentiality.

### *Serious games for collaboration and research*

Zyda (2005, p. 26) defines serious game as ”a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives.” Dörner et al. (2016) consider that serious games must be intended by the developers to include training or pedagogical goals. Serious games have been used as an approach to learning in curricular areas such as health, business or social issues (Connolly et al., 2012). Additionally, they have been used for example to carry out government or corporate objectives (Zyda, 2005) and in urban planning (e.g. Poplin, 2012), behavior change in substance abuse (e.g. Verduin et al., 2013), and to support collaborative interactions (Boyle et al., 2016). They are also used for research purposes in the form of gathering and analyzing data (e.g. van Riel et al., 2017; Sun et al., 2016; Mohan et al., 2014).

Collaboration in games can be divided into three categories: instinctual, supportive and integrative collaboration (Azadegan & Harteveld, 2014). Of these, integrative collaboration is the one used most in serious games because it gives the players time to do decisions on the cognitive level, and therefore highlights the mechanics that support the learning content. Communication is in a central role in collaborative games and restricting or supporting different means of communication can change the nature of the game (Beznosyk et al., 2012; Zagal, 2006).

The purpose of a serious game is twofold in the way that it should be both entertaining and educating at the same time (Bellotti et al., 2010). Therefore, the design process of a serious game is more demanding compared to either purely entertainment or educational purposed games. Rigorously designed and tested serious games simulating real processes can be used to gather research data from complex systems that otherwise are difficult to study.

## 3 Designing a serious game for research

### *Research approach*

The motivation for design science research (DSR) emerges from the desire to improve the environment with new artefacts and from processes to build the artefacts. Design is the process of taking action to change the existing situation into a preferred one (Simon, 1996). Klabbers (2003b) calls the aim to change the situation to a preferred one design-in-the-large and the construction of an artefact design-in-the-small. He adds that the purpose of design-in-the-large is to see the design broader than the material artefacts, especially in cases of complex social systems where predicting the behavior of the system is difficult. Opposite to social systems, material systems are expected to behave as designed (van Aken, 2014).

Design-oriented research in social systems is more complicated than in material systems, because the links between the artefact and the outcomes are shallower and generalizing the artefact in social systems is much more difficult (van Aken, 2004). In the case of social systems, design artefacts merely attempt to enhance the properties of the system presented in the design problem (Klabbers, 2003a). The contents of the artefact are communicated to the target group, and they are motivated to learn to use it as designed (van Aken et al., 2016) so that the outcomes can be studied even though the behavior of the system cannot be predicted. DSR produces artefacts used to deal with field problems, but also possible extensions to the original theories and methods used in defining the context and developing the artefact (Hevner, 2007). Field tests and evaluation of the artefacts also provide experience in conducting research in the application environment.

Games are examples of design artefacts (Klabbers, 2003b) and serious games are purposefully designed to educate or train the players, and they can be used to reflect a real situation through simulation. A game is controlled with a set of rules that must be communicated to the players to provide a frame for interactions, which form the resulting knowledge (Klabbers, 2003a). While playing games, the participants or players may not be aware of the reasons why they act how they act and a computer as an interface between the player and the game can further hide the structure of the game and encourage instinctual action. The designer of a game artefact should not only be aware of this factor of design-in-the-large but also use it in the design-in-the-small by shaping the elements of the game accordingly (Klabbers, 2003a).

Hevner et al. (2004) present DSR in three cycles: relevance, design and rigor. The relevance cycle connects the context of the research project to the activities in the design cycle, and the effect of the design artefact is evaluated through field testing in the relevance cycle. The rigor cycle connects the knowledge base and tools to the design cycle and ensures the innovation of the research project (Hevner, 2007). Thorough research of the knowledge base is necessary to guarantee that the design artefacts produced are not based on already known applications (Hevner et al., 2004). The design cycle in the center of the research produces and evaluates a design artefact or artefacts. Hevner's approach to DSR comes from information systems research and is useful to adapt when the artifact is a digital game. Another approach would be for example Van Aken's (2004) DSR process in three designs: object design, realization design and process design.

*Current study*

The DSR process for EcoGame is presented in Figure 2. The game development process of EcoGame is presented as a part of the design cycle in Figure 2 and as its own in Figure 3. For designing the game artefact, the background is drawn from the knowledge and environment bases through rigor and relevance cycles. The knowledge and environment bases are grounded on the concepts and literature presented in the introduction to this paper. The DSR process for EcoGame is ongoing and the design artefact improves through each round of field tests conducted. Contributions from the EcoGame artefact to the environment and knowledge bases will be part of further research using the research data gathered with it.

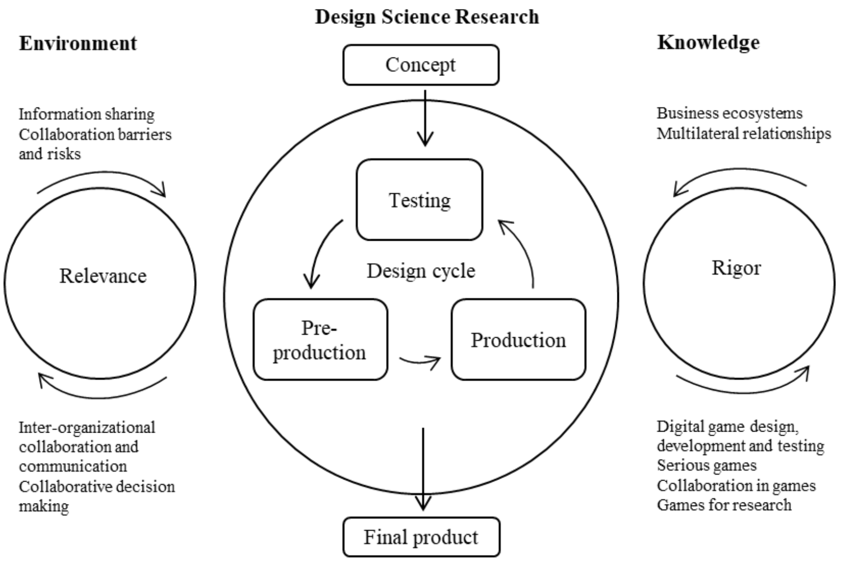


**Figure 2** Three-cycle DSR for EcoGame (adapted from Hevner, 2007)

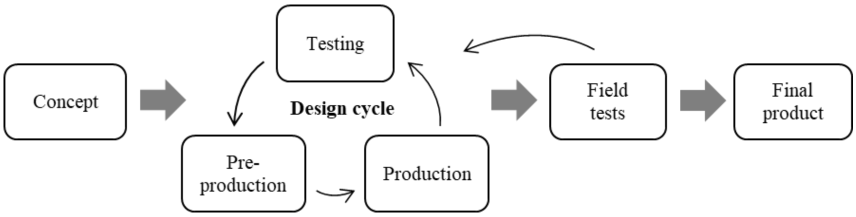


**Figure 3** Development process of EcoGame

The creatively demanding process of serious game development requires an iterative production process that can be seen in Figure 3. Due to the cyclic production in game development, the development process fits well into DSR where the design cycle requires a continuous evaluation of the artefact. The purpose of field testing in DSR is to produce input for redesign of the artefact (van Aken et al., 2016). The testing inside design cycle (see Figures 2 and 3) is internal testing of the EcoGame as a tool conducted by the designers whereas field testing is using the game for its designed purpose and gathering data for research and further improvement of the design artefact.

### *EcoGame design*

The centerpieces of EcoGame are the maturities of the companies and the benefit-cost ratios of projects performed by the companies. The maturity of an individual company is presented as six attributes (risks, agility, innovation, market, specialization, and network) based on the collaboration variables presented by Abreu and Camarinha-Matos (2008). The maturity determines the level of projects available for the player as well as the starting budget for each game round. Overall, the players complete projects throughout the game and the success of each project is displayed as a benefit-cost ratio. To successfully plan and complete projects, the players representing companies need to informed collaborative decisions. At the end of the game, the result is shown as one benefit-cost ratio taking into account all the projects completed.

An EcoGame session can be divided into four phases: game session preparation, individual preparation, player interaction and gameplay, and scoring and evaluation. The phases are presented in Figure 4 together with the different elements of EcoGame information provided and received by the game, players and facilitators. Each phase has its own objective. First phase simulates the real ecosystem within EcoGame. In the second phase, players are immersed in the game and adopt their roles within the simulated ecosystem. If the players are from the simulated ecosystem, role descriptions and role adoption in the first two phases are lighter and more to describe how the roles were transferred from reality. Third phase, the actual gameplay, fills the purpose of a serious game through entertainment and learning. During third phase, most of the data from EcoGame phases overall is generated, for example by videotaping the session and recording all actions made by players. Fourth and the final phase evaluates the success of the game and through discussions confirms the fulfillment of serious purpose. Feedback about the game and its success are gathered throughout the phases in the forms of oral feedback, reporting and after game survey.

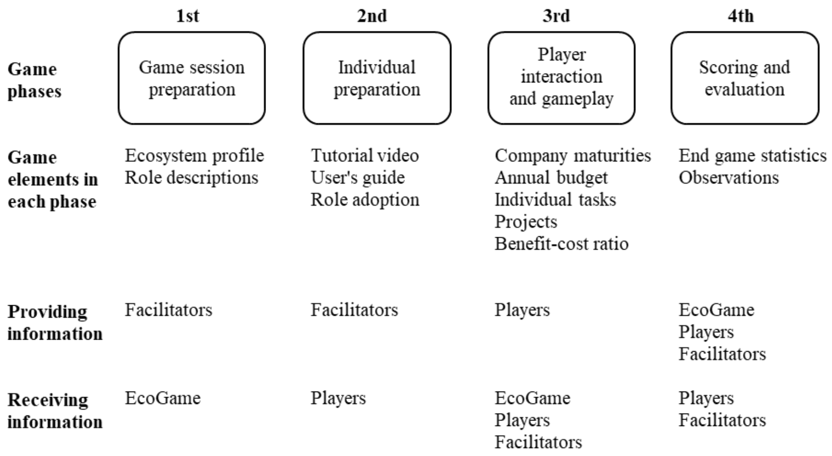


**Figure 4** EcoGame phases, elements and information provided and received by the game and participants of a game session

The gameplay of EcoGame is divided into game rounds. A game round consists of carrying out projects and performing tasks. During one round, each company starts one project and chooses the partners they can and want to share the project with, if any. To participate in another player's project one must meet the same maturity requirements of the project than the one starting the project. The benefits gained from projects in the game are distributed between all the players investing in it. In general, the larger the scale of a project, the more resources it requires and the better reward it can yield. The companies' maturities can be developed through projects or smaller tasks that are individual operations for each company, performed at any point during the game rounds. A player's view, where the game mechanics described in this section are present, is shown in Appendix 1 (Figure 5).

While carrying out projects, communication between the players is in a major role. Especially in the beginning when the companies may be in very different situations and cannot share many projects with each other. If the companies wish to complete large projects successfully later in the game, they need to communicate their capabilities and available resources to be able to make optimal collaborative decisions. Communication about budget, attributes and resources in game is the kind of sharing of sensitive information the players are not comfortable in doing in real multilateral collaborative decision making situations.

The companies set goals both individually and together as an ecosystem after setting up the game, but before beginning to play. The goals, the benefit-cost ratio of the ecosystem and individual maturity growths control the gameplay and define in the end how successful the game session has been. The goals might be difficult to set for the first game session, and therefore it is advised that the players go through the optional preparation, including watching a tutorial and reading user's guide. Additionally, the players can play a test round to familiarize themselves with the game in the beginning of the game session.

The game is scored both individually and ecosystem-wise. One scoring factor applied to both individual companies and the whole ecosystem is the ratio between benefits and costs. The other factor, the change of the maturity level of the company, is applied only on individual level. The changes in maturity level cannot be compared between the players within one session, as the starting situations of the companies can differ. The setting of the game guides what information is relevant to be shared from the start. If the companies in the ecosystem of the game are set to be on similar maturity levels, the projects they start are accessible for all players. A more difficult setting, in the sense of requiring more information sharing, would be when the companies of the ecosystem are on very different maturity levels and therefore would have to put work into developing their maturity levels before being able to execute highly beneficial projects together.

## 4 Results of generating data with EcoGame

### *Research setup for gathering ecosystem data*

The setup for field testing EcoGame and gathering research data with it has been organized with master's level university students for four consecutive years so far and continues every autumn. These tests are part of the field testing of EcoGame as DSR artefact. The basic setting with students has been organized so that the players represent companies of a real business ecosystem in teams of two to four people. The real business ecosystem is simulated within EcoGame utilizing an ecosystem profile within forestry industry (see Ylönen et al., 2021). Each team has their own game interface and input decisions themselves. A game session lasts two to four hours and includes two to six game rounds. During the game sessions there have also been two facilitators present making observations and ensuring the game works as intended and research data gathered is relevant. An example picture from a game session organized physically in same location can be found in Appendix 2 (Figure 6) but the game sessions can also be organized remotely.

The field tests with students followed the game phases presented in Figure 4. In the first set of field tests in 2017, four game sessions were organized each consisting of six students in pairs. In total 24 students out of the 198 participants on a master's level university course took part in EcoGame. Next year, 19 out of 38 participants in the same course took part in EcoGame. The second set of field tests differed from the first ones by each of the three game groups playing through two game sessions instead of just one and reflecting on their experiences more with an interim report. The third consecutive year of field tests saw 67 of 73 students in the course participating in EcoGame. They were distributed in seven game groups and played two game sessions as in previous year. Fourth consecutive year of tests was participated by 84 of 85 students on the course and was organized completely comparatively to the third tests except the game sessions were organized remotely instead of physically gathering to one location. This time the participants were distributed in eight game groups. The evolution of test settings through the first four years are presented in Table 1.

All players participating in EcoGame field tests conducted so far have given consent to recording the game sessions and using the data gathered for research purposes in anonymized form. As such, the research reported in this paper does not require separate ethical review in Finland according to guidelines provided by the Finnish National Board on Research Integrity TENK.

**Table 1** Evolution of field test rounds conducted so far

| | *Pre-game report* | *Game session 1* | *Interim report* | *Game session 2* | *Change in game setting* | *Change in decision makers* | *Final report* | *Survey* |
|---|---|---|---|---|---|---|---|---|
| ***1st tests*** | x | x | | | | | x | |
| ***2nd tests*** | x | x | x | x | | | x | |
| ***3rd tests*** | x | x | x | x | x | x | x | x |
| ***4th tests*** | x | x | x | x | x | x | x | x |

The main changes between the sets of field tests were the addition of second game session, changes in the setting of the game and the composition of decision makers, and addition of a survey after both game sessions. The second game session was added due to player feedback about difficulties of getting into the game and setting and reaching goals. “The game took two rounds to get into” said Team P1 in their final report in 2017 (all quotations from players are translated to English by authors). “For education there could be two game sessions instead of one. The learning content acquired with the game could be better utilized when its clear what the game is about.” Team VH2/2017 final report.

With an interim report and second game session, the players have reported that they are able to prepare proper strategies and play the game instead of using most of the session learning to play. “The first time [first game session] our strategy was ‘rather oops [try and fail], than what if’ … For the second game session we had a clearly more coherent strategy for our company.” Team VH2/2019 final report.

Change in game setting was made to make the situation of the simulated ecosystem more realistic in the second game session and collaboration more difficult due to big differences in the resources and maturities of companies. In addition, one team was swapped with another playing the same role in other game group. Both disruptions made noticeable difference to the players even though the simulated ecosystem and projects carried out were the same. “The change in the ecosystem [structure] affected the collaboration between companies by quite a bit. Like previously mentioned, the whole ecosystem worked more openly in the second game session.” H8/2020 final report. “The change in maturities was remarkable and we reacted to this too slowly.” H1/2020 final report. Changes in key personnel within a company are common and affect to the collaborative structures as well and it is an interesting aspect to study. Finally, a survey was added to gain quantitative data about the disruptions and the game in general.

### *Field testing results*

The four sets of field tests conducted have provided vast amounts of both qualitative and quantitative data. The collected data sources are gathered in Table 2 by the phase it is created in and by the game or actor that is the main contributor in generating or recording the data (see also Figure 4 for phases and contributors). The sources where players contributed (reports and survey) and the questions asked in them are presented in Appendices 3-6. In brackets after the source is mentioned whether the data is qualitative, quantitative, or a combination of both. Table 3 breaks down the data sources into topics that so far have been found relevant.

**Table 2** Data gathered with EcoGame by game phases and main data contributor

| | ***Player*** | ***Facilitator*** | ***EcoGame*** |
|---|---|---|---|
| ***Game session preparation*** | | Ecosystem profile (Both) | |
| | | Game settings (Both) | |
| ***Individual preparation*** | Pre-game report (Quali.) | | |
| | Interim report (Quali.) | | |
| ***Player interaction and gameplay*** | | Recordings (Quali.) | Gameplay data (Quant.) |
| | | Observations and notes (Quali.) | Software related data (Quant.) |
| ***Scoring and evaluation*** | Final report (Quali.) | | |
| | Survey (Both) | | |

**Table 3** Topics relevant for research by game phase and nature of data

| | ***Qualitative*** | ***Quantitative*** |
|---|---|---|
| ***Game session preparation*** | Project and task contents<br>Project and task parametres | Financial state of ecosystem<br>Company maturities |
| ***Individual preparation*** | Ecosystem structure<br>Analysis of collaboration, trust and power relations<br>Potential collaboration strategies<br>Feedback about game and role adoption | |
| ***Player interaction and gameplay*** | Player behavior<br>Communication<br>Development of collaboration | Benefit-cost ratios<br>Project and round durations<br>Technical events |
| ***Scoring and evaluation*** | Analysis and reflection on strategies and results of second session<br>Feedback about game, its use for learning and its capabilites on simulating reality | Survey data on understanding of ecosystem concept, learning with EcoGame and user experience of playing EcoGame |

The game session preparation produces both qualitative and quantitative data through implementation of the profile of the business ecosystem (see Ylönen et al., 2021). These data are used in evaluating the success of simulation of the real ecosystem within EcoGame. The data from reports in individual preparation and scoring and evaluation phases are used to get the players' view of the success of the simulation. "The theme of the game was meaningful as networks of companies increase all the time. The real companies and their network made the theme more concrete." H3/2018 final report.

The starting point for data gathering in player interaction and gameplay was to videotape the game sessions so the behavior of players and development of communication and collaboration could be analyzed afterwards. For remote game sessions, the discussion and chat were recorded. Additionally, facilitators make qualitative and quantitative observations to support the recordings, but the observations during gameplay are not required as the observations would be available in other sources of data.

The reports from players at different points (pre-game, interim between sessions, and final after both sessions) provide subjective reflection from the players' point of view that go well together with the recorded data. For example, in second game session for group 4 in 2020 (teams P4, VH4 and H3) it was reported by both P4 and VH4 that collaboration with H3 was difficult as they were difficult to communicate with. From H3's final report it can be seen that they chose to compete within their business ecosystem and compare their individual successes instead of aiming for joint success. These points are well reflected in the recording of the session as P4 and VH4 were openly collaborating and communication throughout the game session but H3 concentrated on discussing themselves in their own room and mainly arrived to communicate with other teams when they needed resources from them or had abundant resources they were able to share.

The main sources of quantitative data are during the last two phases. The EcoGame itself records every input and result of the game and allows analysis on how well individual projects were simulated in the game and did they meet the expectations of players. For example, if a project is approached and rationalized by players in very different ways and the results are disappointing, the reason might be in the project not being simulated well enough. The game also reports the result of the game, the benefit-cost ratio which allows comparison between different game groups and between game sessions of one group. Overall, the different types of data support each other in improving the design of EcoGame towards the final product in its DSR process, providing managerial results, and offering new directions for research in ecosystem dynamics.

The students participating in the test sessions were overall satisfied with the game experience. In the survey conducted after both game sessions in 2019 and 2020, 121 out of 151 players agreed that playing EcoGame was meaningful (Likert scale 1-5 of which 4 somewhat agreed and 5 strongly agreed; Appendix 6 question 32) and 110 out of 151 would agree to play EcoGame again with a different theme (Appendix 6 question 34). In general, the players adopted their roles well (143 out of 151, Appendix 6 question 2) and found the context of forestry industry appropriate. The industry is nationally remarkable and most of the students found it familiar and therefore the roles were easy to get into (135 out of 151, Appendix 6 question 7). It is also worth noting that even though majority of players so far have responded positively to EcoGame and its serious purpose, there have also been players that did not find it meaningful or suitable for learning. EcoGame is a novel way to study and improve collaboration in business ecosystems but like any tool, it is not suitable for every situation where problems in collaboration exist.

## 5 Conclusion

EcoGame is a serious game that simulates decision making in multilateral relationships, where lack of information sharing is a barrier to increasing and realizing the benefits of collaboration (Kajüter & Kulmala, 2005; Windolph & Möller, 2012; Sinkkonen et al., 2013). The decision making situations and communication occurring during play are supposed to provide information comparable to real collaborative decision making processes in business ecosystems playing EcoGame. This is achieved by transferring the ecosystem profile of a real business ecosystem into the game (see Ylönen et al., 2021). The game mechanics of EcoGame by design promote collaboration over competition and emphasize the role of communication in multilateral relationships. However, the game does not restrict competition either. All this is recorded in several types of data allowing multilateral relationships to be studied better than currently possible.

Two research questions were set to be explored in this research paper:

1. How to design a serious game that simulates collaborative decision making in multilateral relationships of business ecosystems?

EcoGame is a serious game and a research artefact following design science research approach for its design, development and testing in the field. The cyclic nature of both design science research and game development process allows the continuous development of EcoGame towards a tool for research and learning in ecosystems. EcoGame incorporates simulation of a real ecosystem by bringing an ecosystem profile as the context of the game. Business ecosystems consisting of multilateral relationships are complex systems and simulation within games is known to be a good method for studying complex systems (Bekebrede & Mayer, 2006). EcoGame is played by three groups representing companies of a real ecosystem simulated within the game. Three actors is the smallest amount that can form a multilateral relationship and at the same time is the easiest to simulate and therefore currently implemented in our research setup for field tests of EcoGame. As mentioned by Iansiti and Levien (2004), it is important to identify small groups of companies close to each other within an ecosystem to draw conclusions of the whole.

2. What types of qualitative and quantitative data for future research are generated from field tests of the serious game?

EcoGame gathers data in various forms and the data sources can be further broken down to topic relevant for research (see Tables 2 and 3). One immediate use of the data is to determine how successful the simulation of the real business ecosystem within EcoGame is and how well the serious purpose of the game has been transmitted. Examples of collected qualitative data include game setting, player reports, and recordings of game sessions. Currently quantitative data gathered is related to the ecosystem profile, outputs from the game software and a survey after to players after the game sessions have been played.

### *Future Research*

As a DSR artefact, the design process of EcoGame is ongoing. While the managerial impact will be verified through thorough field testing, EcoGame provides a vast amount of data for other research purposes. With EcoGame, we can study multilateral relationships in business ecosystems – e.g. how companies make collaborative decisions, how they organize information sharing, what they share and why, how the relative strength of companies affects the collaboration and communication. The dynamics of business ecosystems are difficult to observe, and therefore simulating certain processes of them within a serious game provides us a way to study business ecosystems and their decision makers.

At the managerial side, a properly tailored EcoGame session can help the decision makers of an ecosystem to get to know their partners better and determine their current level of collaboration and decision making skills. The game session is a risk-free environment for the players to try different means of collaboration and communication. In these cases, EcoGame provides valuable data on different scenarios business ecosystems might face – for example, forming of a new ecosystem, taking on a new partner in an existing ecosystem or changing of a key person resulting in a change in personal relations. EcoGame has already been used to study forming of a new ecosystem in two different research projects. In these two projects, EcoGame was played with researchers adopting roles within the contexts of the new forming ecosystems. The data from these games were used for example to forecast profits and losses, balance sheet structure and valuation of a startup. Additionally, the games were used for training potential new startup entrepreneurs into collaborative decision making in an ecosystem.

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## APPENDIX 1

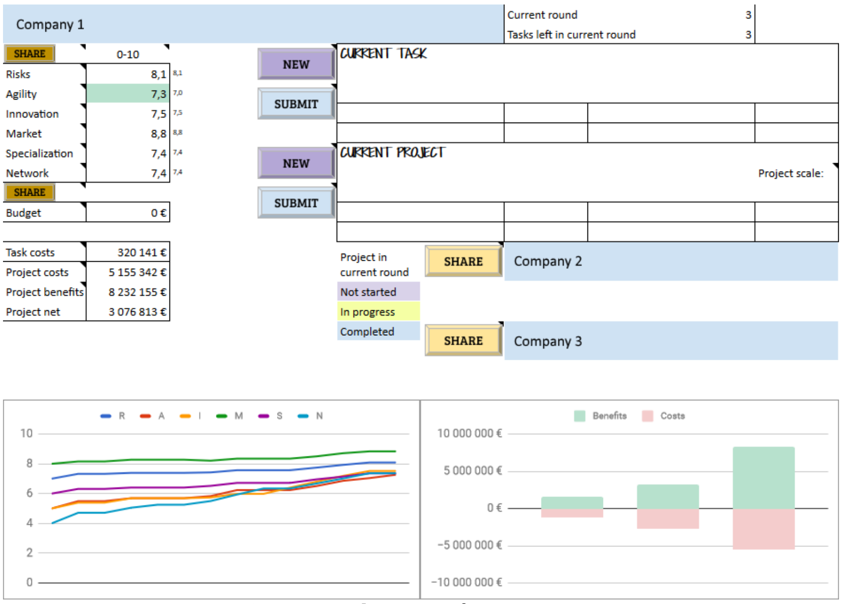


**Figure 5** A player interface in EcoGame

## APPENDIX 2

**Figure 6** A field test setting with students

## APPENDIX 3

This appendix presents pre-game report tasks that the players of EcoGame have answered before their first game session. The tasks are open-ended and the players received links to some relevant webpages and financial statement of the company they represent as attachments to the tasks.

*The business ecosystem in EcoGame consists of three actors (Ponsse, Herman IT and Veljekset Hokkanen). Familiarize yourself with the ecosystem and picture the relationships between the actors. Describe and clarify the contents of the connections between companies.*

## APPENDIX 4

This appendix lists interim report questions that the players of EcoGame have answered after their first and before the second game session. The questions are open-ended and are divided in two parts: analysis of game and feedback.

*Part 1: Game analysis*

*Analyse the results of your first game session with the help of the results-file (available in course Moodle).*

- *How did the game succeed from your company's perspective? Ecosystem's perspective?*
- *Did utilization of collaboration succeed? Did collaboration develop during the game?*
- *Consider matters effecting collaboration. For example, trust (towards individuals/companies), power relations between companies, long term engagement.*
- *What kind of strategy did you have for the first game session? What kind of collaboration strategy will you have for the second game session for your company? For your whole ecosystem?*

*Part 2: Feedback on…*

- *Playing experience*
    - *implementation of the game so far (pre-game task, test round, first game session…)*
    - *implementation of the game remotely (if applicable)*
- *Role adoption (how well did you get into your role, sufficiency of pre-game material…)*
- *Playing the game (understanding game mechanics, game logic…)*
- *What to improve? (good/bad/to improve about game)*
- *Other feedback about game*

## APPENDIX 5

This appendix lists final report questions that the players of EcoGame have answered after their second game session. The questions are open-ended.

*Game analysis:*

*Analyse the results of your second game session with the help of the results-file (available in course Moodle). Compare the second game session with the first one.*

- *How did the game succeed from your company's perspective? Ecosystem's perspective?*
- *What kind of strategy did you prepare for second game session and how agile was it to adapt to the changes made for second game session (ecosystem actors, company maturities and budgets)?*
    - *Did you succeed in implementing your planned strategy? Why, why not?*
    - *Company maturity waw used to describe how ready the company was to collaborate within the ecosystem and it also affected to the available budget. The change in maturities was noticeable between game sessions, were you able to react to this change appropriately?*
    - *Did you utilize results and experience from the first game session in preparation of/during the second game session?*
- *How did the change in ecosystem actors (players representing Herman IT changing) affect…*
    - *Operation of your company?*
    - *Strategy of your company?*
    - *The collaboration established during the first game session?*
        - *Were there any differences in factors of collaboration (e.g. trust, openness, power relations, engagement) between game sessions?*
        - *Did you succeed in collaborating as planned?*
    - *Other observations in regards the change affecting collaboration?*
- *Other observations about the game sessions and the comparison of them?*

## APPENDIX 6

This appendix lists survey questions that the players have answered after their second game session. The questions are closed-ended (unless mentioned otherwise). The choices follow a typical Likert scale format: 1 Strongly disagree; 2 Disagree; 3 Neither agree nor disagree; 4 Agree; 5 Strongly agree.

1. *I played the role of company… (Choices: Ponsse, Veljekset Hokkanen, Herman IT)*
2. *I adopted the role of my company well.*
3. *(If you answered 1) Why? (Open ended, optional)*
4. *The pre-game task to adopt the company role is necessary.*
5. *(If you answered 1) Why? (Open ended, optional)*
6. *Being previously familiar with team members makes playing easier.*

7. *The theme of the game was set in forestry industry. The theme was easy to internalize.*
8. *(If you answered 1) Why? (Open ended, optional)*
9. *The goal of the game (benefit/cost-ratio) was clear.*
10. *(If you answered 1) Why? (Open ended, optional)*
11. *I was able to connect situations within game to situations in real life.*
12. *(If you answered 1) Why? (Open ended, optional)*
13. *The game was suitable to the contents of this course.*
14. *(If you answered 1) Why? (Open ended, optional)*
15. *Central to the game was inter-organizational collaboration. The game was successful in educating about this topic.*
16. *(If you answered 1) Why? (Open ended, optional)*
17. *The game educated me about collaborating with multiple actors in a multilateral relationship.*
18. *(If you answered 1) Why? (Open ended, optional)*
19. *The game is used to practice decision making situations involving multiple (3) actors. With the game I learned about different behavioural models.*
20. *(If you answered 1) Why? (Open ended, optional)*
21. *I recognized the different starting situations (maturities and budgets) of each company and took them into account during negotiations.*
22. *(If you answered 1) Why? (Open ended, optional)*
23. *I recognized different components of collaboration while playing the game (e.g. trust between companies, openness, power relations, engagement)*
24. *(If you answered 1) Why? (Open ended, optional)*
25. *The second game session was essential for educational purpose.*
26. *(If you answered 1) Why? (Open ended, optional)*
27. *The change in the ecosystem (change of Herman IT players) had positive impact to the game experience.*
28. *(If you answered 1) Why? (Open ended, optional)*
29. *The change in the ecosystem (change of Herman IT players) had positive impact to the end result of the game.*
30. *(If you answered 1) Why? (Open ended, optional)*
31. *The language of the game's user interface (English) made playing difficult.*
32. *Playing the game was meaningful.*
33. *(If you answered 1) Why? (Open ended, optional)*
34. *I would play the game again with another theme.*
35. *(If you answered 1) Why? (Open ended, optional)*
36. *The amount of game mechanics made playing difficult.*
37. *Individual players had bigger effect within the game than the companies that they as a team represented.*
38. *Open feedback about game. (Open ended, optional)*
39. *(If applicable) Open feedback about organizing game remotely. (Open ended, optional)*

# Publication IV

Rissanen, M., Metso, L., Sinkkonen, T., and Kärri, T.
**Recognizing Life Cycle Benefits of Real Time Fatigue Monitoring for Ecosystems**

In: Ball, A., Gelman, L., and Rao, B. (eds) Advances in Asset Management and Condition Monitoring. Smart Innovation, Systems and Technologies, 166, pp. 417–428, 2020

# Chapter 35
# Recognizing Life Cycle Benefits of Real Time Fatigue Monitoring for Ecosystems

**Matti Rissanen, Lasse Metso, Tiina Sinkkonen, and Timo Kärri**

**Abstract** Real time fatigue monitoring creates various benefits in multiple categories appearing at different points of the item's life cycle. One monitoring and analytics service can be beneficial for a large set of actors, an ecosystem. An ecosystem consists of actors that work towards a common goal, a focal value proposition. In our case, this focal value proposition is management of an item's life cycle in real time. The purpose of this paper is to recognize benefits related to real time monitoring and analytics of fatigue in welded steel structures and to recognize a set of actors that can form a new ecosystem for creating these benefits. The benefits are recognized in interviews with practitioners who observe the lack of reliable analytics in the remaining life of the items they design, manufacture, maintain or operate. The interviewees represent different parts of an item's life cycle and during the interviews are asked to recognize and rank benefits and to form a potential new ecosystem from their perspective. The recognized benefits are for example in improving communication between product design and production, improved maintenance scheduling, prolonged production time, correctly timed replacement investment decisions. The interviewees do not form a unified opinion of a new ecosystem but rather we recognize two categories of companies that form the basis for future research in the subject. The interviewees agree that real time monitoring holds huge potential for benefits but is not yet adopted in large scale in practice.

## 35.1 Introduction

Welded steel structures are designed to sustain certain amount of fatigue in certain conditions but when the conditions are not default but rather varying, e.g. weather or operational effects, the life of the whole item does not follow its design. This causes problems when trying to operate the item affected by fatigue damage optimally. For example, based on our interviews, maintenance is scheduled more often

M. Rissanen (✉) · L. Metso · T. Sinkkonen · T. Kärri
Industrial Engineering and Management, LUT University, Lappeenranta, Finland
e-mail: matti.rissanen@lut.fi



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than necessary to prevent failures and the item is replaced before the real end of its life because reliable information on the remaining life is not available.

Refamo is a research project of a real time fatigue monitoring and analytics system for determining the remaining life of a welded steel structure. The interviews conducted in Refamo discussed the benefits of such a system in bigger scope than the specific system can be applied to currently. The interviews provide views on benefits of real time fatigue monitoring in a general level and at the same time help develop the system under research further. In this paper, Refamo refers to real time fatigue monitoring.

By applying Refamo to the item facing varying conditions through natural or human causes, the real end-of-life point can be determined and momentary fatigue to the item at any time during monitoring can be determined and analysed. For example, for heavy equipment used in mining, one of the main issues is fatigue caused by natural causes [1] and Refamo can help manage it. We use the term ‘item’ throughout this paper to discuss the different equipment, machines and structures that were subjects of our interviews. [2, p. 12] defines ‘item’ as “part, component, device, subsystem, functional unit, equipment or system that can be individually described and considered”.

An ecosystem in a business context is a concept that considers companies and their relations that are not limited to any one industry [3, 4]. The actors within one interact with each other to realize a common goal, a focal value proposition [3]. When we consider an ecosystem that forms around Refamo, we can have various actors operating in different points of an item’s life cycle. For example, an ecosystem can consists of the manufacturers of an item (even if they compete with each other), a monitoring and analytics provider, an operator of the item, a maintenance partner, a research institute studying something related to the item, regulators making regulations based on confirmed data, professional organisations, and so on. This paper discusses the benefits of using Refamo throughout the life cycle of an item and the new ecosystem to be created. In this study, we look to answer two research questions through interviews with practitioners:

RQ1: What are the main benefits of using Refamo?
RQ2: Which set of actors can form a new Refamo ecosystem?

## 35.2 Literature Review

Condition-based maintenance (CBM) has been used in automated manufacturing in which condition monitoring is understood to contain data acquisition, processing, analysis, interpretation and extracting information [5]. Vibration analysis has been done with rotating parts in an engine because vibration is one element to cause minor or serious problems to a machine [6].

Structural health monitoring (SHM) can be seen as a strategy for damage identification in aerospace, civil and mechanical engineering infrastructure. SHM is based on periodical measurements [7]. SHM in real time can reduce inspection and repair costs. The other advance in SHM is lifetime monitoring of any construction projects. For example, Jindo Bridge was a collaborative project between participants from US, South Korea and Japan to real time monitoring. It was the largest project to monitor a bridge with wireless sensors. A lot of data collected and analysed in the project [8].

[9] examined the implementing of long-term SHM in large-scale bridges. Bridges are unshielded from environmental conditions—humidity, wind, solar-radiation and temperature as well as operational effects—traffic and other loads. SHM can give a new way to inspect and monitor the safety of bridges.

Condition monitoring systems have been used in wind turbines and helicopter gearboxes online measurements [10]. Condition monitoring is needed in wind turbines because those are unmanned and located far away from maintenance service providers. Wind turbines are under unkind weather conditions, e.g. wind, heat, cold, lightning, rain, ice and snow. Monitoring the condition of wind turbines preventative maintenance can be adopted instead of corrective maintenance [11]. Many operational fields (e.g. ports) operated with heavy equipment are becoming staffed with less people and therefore there is a need to monitor the equipment and their use in real time [12]. The monitoring and analytics can help in improving the operation of the fields and provide data for operational planning [13]. Successful preventive maintenance operations reduce the unscheduled downtime of an item and therefore can improve the productivity during its life cycle [14]. [15] note that deterioration and failures in items that do not wear evenly during their use can cause high costs or safety hazards. Excessive maintenance can, however, eliminate the cost benefits [16].

[17] consider condition monitoring, life extension, repair versus replace, and optimized life cycle management the most important issues of item life cycle management. Said issues are also of the essence in our research as real time fatigue monitoring in some cases aims to extend production time of an item, provides accurate information on when the items end-of-life is, and allows optimal life cycle management through flexible scheduling of maintenance operations. In some instances, the fatigue on items is highly dependent on how it is operated and the benefits from monitoring the item extends further than maintenance management.

## 35.3 Research Design

This study is based on data from seven qualitative semi-structured interviews. For structuring the interviews, we adopted the localist position (see [18]) since we are looking into a complex organizational phenomenon of organizations forming an ecosystem to work towards a common goal with a real time fatigue monitoring and analysis technology and tool. Semi-structured interview consists of prepared questioning within pre-determined themes [18].

The interviewees were chosen based on initial market analysis on national level that recognized these companies as potential benefiters of Refamo and key actors in a new Refamo ecosystem. The companies were also chosen to represent a wide scale of industries and positions in an item's life cycle. The interviewees' titles and the fields of business of their companies are presented in Table 35.1 and their position in item's life cycle is presented in Fig. 35.1. The companies are encoded with letters from A to G and in further sections of this paper the interviews are referred to with the respective company letter. Company G gave us two interviewees and many others mentioned that the questions we sent them beforehand were discussed by a group of people to give us wider perspective from the interviewed company rather than just one view. The interviews were conducted by a team of three university researchers—two concentrated on the benefits and ecosystem of Refamo, one on the technical perspective and expertise in welded steel structures. With this kind of team we could acknowledge the different backgrounds of interviewees by being able to contribute to the discussions raised by our interviewees.

Our interview consisted of four themes: product, data, value, and business model. Each theme formed around 2–4 pre-determined questions. The interview themes and questions can be found in Appendix 1. In addition, two surveys were conducted during the interviews. Surveys are used to gather information systematically in a quantitative form [20]. Our surveys were used at the end of value and business model themes to summarize the otherwise qualitative interview and potentially highlight important points that went unheeded. The first survey used the Likert-type scale to rank benefits relevant in the opinion of the interviewee. In the second survey, the interviewees created their own Refamo ecosystem by placing potential stakeholders in a circle where the scale was from one to five—one meaning little relevance and five high relevance within the ecosystem. The mapping of the ecosystem was done in similar manner as in research by [21]. The interviewee could also leave pre-determined potential stakeholders out of the circle or add their own ones.

**Table 35.1** Interviewees and their fields of business

| Field of business | Company | Title of interviewee |
|---|---|---|
| Construction engineering | A | Senior structural expert |
| Maintenance and engineering services | B | Maintenance manager |
| Power plant operation | C | Investment portfolio manager |
| Civil engineering | D | Bridge specialist |
| Heavy equipment production and services | E | Test engineer |
| Heavy equipment production and services | F | Research and development manager |
| Power plant operation | G | Managing director |
| Power plant operation | G | Project manager |

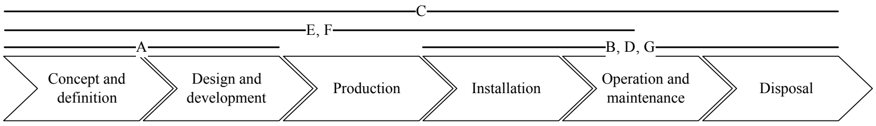


**Fig. 35.1** Life cycle of an item and involvement of interviewed companies during it. [19]

## 35.4 Results

### *35.4.1 Benefits from Using Refamo*

The main results in regards to benefits recognized from interviews are gathered here from each interview. Table 35.2 summarizes the results of the first survey with the most important benefits highlighted in colour in the case of company preferring some 5 rated benefits over others. If the company found all 5's as important, they are all coloured.

A considers that they are not a potential user of Refamo since the items they design have to be designed in a way that they last in any conditions the designed amount of lifetime. They see their field of business as so conservative that even when there are benefits to using Refamo but the value might not be great enough for Refamo to be used. However, the benefits from using Refamo in large items with massive amount of welded structures could come from monitoring critical components and then the interested party would be the supplier of said components. Another benefit comes from automating some scheduled manual measurement operations. Instead of analysing the end-of-life point, the conservative industry could be interested in an analysis of how the item is not failing, and how some standardized scheduled measurements could be made automatic and safer.

B emphasizes the role suppliers of items in using Refamo in concept, and design and development phases of item's life cycle. In process industry, the biggest benefit and financial value from real time monitoring comes through reduced unexpected and planned shutdown time.

C noted that in process industry fatigue might not be the biggest issue since the loads often are kept as stable as possible. However, they have process items that endure varying loads where Refamo would be beneficial. These items are not the most important ones for C and therefore the financial value to be gained is unclear. In a bigger picture, some items, e.g. steam boilers, are very critical and the company attempts to calculate and simulate the remaining life of these critical items. A failure of such critical item would cause huge costs as downtime. Real time monitoring is something the company has been looking to improve on since there is also interest in using controlled overload to produce more when market demand is higher. Currently, the take on overload on some occasions according to interviewee is: "'Now we will make money—the machine can take it.' Sometimes they last, sometimes they do not. It (the decision of overloading) is not based on any data."

**Table 35.2** Survey on benefits of Refamo

| | A | B | C | D | E | F | G | Avg | Mode |
|---|---|---|---|---|---|---|---|---|---|
| **Concept, design and development** | | | | | | | | | |
| Load and fatigue information for research and development | 5 | 5 | 5 | 2 | 5 | 5 | 3 | 4,3 | 5 |
| Data storaging and later analyses | 5 | 4 | 4 | 2 | 5 | 5 | 5 | 4,3 | 5 |
| Development of design methods and practices | | | | | 5 | 2 | | | |
| **Production** | | | | | | | | | |
| Estimating effects of production quality to item health | 1 | 5 | 4 | 2 | 5 | 4 | 3 | 3,4 | 4; 5 |
| **Installation, operation and maintenance** | | | | | | | | | |
| Maintenance planning and execution | 3 | 4 | 5 | 5 | 4 | 5 | 4 | 4,3 | 4; 5 |
| Monitoring of momentary fatigue | 3 | 5 | 5 | 2 | 5 | 4 | 4 | 4,0 | 5 |
| Real time monitoring of remaining life of an item | 3 | 5 | 5 | 5 | 5 | 2 | 4 | 4,1 | 5 |
| Automated actions in regards of item health | 3 | 4 | 2 | 5 | 4 | 2 | 5 | 3,6 | - |
| Sporadic measurement and analytics services | 3 | 2 | 2 | 4 | 2 | 4 | 5 | 3,1 | 2 |
| Risk management | 3 | 4 | 5 | 4 | 4 | 2 | 5 | 3,9 | 4 |
| Work safety | 3 | 5 | 4 | 2 | 2 | 2 | 5 | 3,3 | 2 |
| Monitoring the user of a machine | | | | | 5 | 5 | | | |
| Training of optimal use of a machine | | | | | 5 | 2 | | | |
| Verifying claims for compensation | | | | | 4 | 4 | | | |
| **Disposal** | | | | | | | | | |
| Forecasting and optimising the remaining life of an item | 5 | 4 | 5 | 5 | 5 | 4 | 4 | 4,6 | 5 |
| Investment decision making | 3 | 5 | 5 | 5 | 4 | 2 | 4 | 4,0 | 5 |

D noted the same as A, that the items are designed conservatively to last their whole lifetime without further monitoring, in D's case for a hundred years. However, the loads have increased during the life cycle of current items maintained by D and the loads are expected to increase in future. This means that the items are unlikely to last as long as designed and in some cases monitoring is already applied to failing items. D considers the same as A that the interest towards Refamo could be more among the companies manufacturing the items and it is difficult to see who would gain value from Refamo and therefore be willing to pay for it.

E involved in large parts of the item's life cycle and producing a heavy equipment directly to end customers sees the benefits from Refamo in two broad categories: benefits in the design and production of the item and benefits in monitoring the end users of items that are also maintained by company E. A big issue for E is that tight competition drives the R&D processes to go through faster and time spent on testing is reduced. Therefore, all monitoring and analytics, including Refamo, that could improve the design process with reduced time spent on testing is highly beneficial. The benefits from the end user category come through improved training and knowledge of items along end users. Better use leads to less maintenance from E's side.

F does not do measuring themselves and mainly does the design and development of their items with established data and methods. Refamo would provide benefits in design through more optimized structures but the interviewee is sceptical if it would be cost-effective. A clear benefit would come through end user training and "forcing the end user to use the machine correctly". F manufactures in a smaller scale same heavy equipment as E and it can be recognized in the interview. Both emphasize the end user perspective and that is why for these interviewees it was included in the first survey.

G is a small service company involved in the installation, operation and disposal of items and their perspective in the interview was on how to benefit the owner of the items they operate. The main benefit from Refamo would be to reliably prove that the items life cycle is longer than designed and therefore would prolong the production time of items. G operates a fleet that is designed for twenty years of production time but they have a gut feeling that the production time could be much longer. However, they do not currently have a reliable data to prove it and Refamo could be beneficial in that regards.

On average, all the benefits surveyed are seen as beneficial by our interviewees (average over 3,0). The ones that have a mode answer of 5 are the most important across the board and can be found in all parts of the item's life cycle. Different interviewees emphasize different parts of the life cycle and for future research they have to be grouped to be fully comparable and the results to be generalizable.

### *35.4.2 The New Refamo Ecosystem*

The second survey conducted during the interviews asked the interviewees to consider Refamo as a focal value proposition (see [3]) in a new ecosystem. Interviewees placed stakeholders they deemed relevant to form the ecosystem and the results are summarized in Table 35.3. Other suppliers included multiple company specific stakeholders and is presented as one. For companies B, F and G, Other suppliers is an average of two answers. Five stakeholders that were only considered relevant by one or two interviewees are not included in the summary.

Variances calculated for the answers show that the only consensus about the new ecosystem is that there is no need to involve the competitors in a central role even if there could be benefits through faster development of the service. From the

**Table 35.3** Survey on potential stakeholders in a new Refamo ecosystem

| | A | B | C | D | E | F | G | Var |
|---|---|---|---|---|---|---|---|---|
| Company represented by interviewee | 2 | 5 | 5 | 5 | 5 | 5 | 4 | 1,10 |
| Interviewee's customers | 5 | 5 | 3 | | 5 | 4 | 4 | 0,56 |
| Competitors | 2 | 1 | 2 | | 1 | 2 | | 0,24 |
| Maintenance service provider | 5 | | | 4 | 1 | | 3 | 2,19 |
| Other monitoring and analytics providers | 2 | | 2 | 3 | 4 | 3 | 4 | 0,67 |
| Steel suppliers | 1 | 3 | 1 | 2 | 4 | 1 | 2 | 1,14 |
| Other suppliers | 5 | 2,5 | 2 | 2 | | 3,5 | 3 | 1,08 |
| End user | 1 | | | 1 | 4 | 4 | | 2,25 |
| Refamo company | 5 | | 5 | 4 | 1 | 2 | 5 | 2,56 |
| Refamo's other customers | 2 | | 1 | | 4 | 2 | 2 | 1,47 |
| University | 5 | 5 | 3 | 3 | 4 | 2 | 3 | 1,10 |

interviewed companies, only A did not consider themselves a potential user of Refamo, the rest placed themselves in the very center of the ecosystem (5) with the exception of company G placing themselves at 4. B, C, E and F offer maintenance services themselves so they did not include other maintenance service providers in the ecosystem creating and sharing benefits of Refamo. In general, the suppliers of interviewees were not seen important in the ecosystem—with some exceptions in A, E and F—but rather the customers of interviewees were considered very important. For E and F the customers include the end users of their items. The role of university and research results in regards to Refamo in the ecosystem varies depending on the interviewees personal background. For example, A has a long research career before their current position and B and E have collaborated with university in research projects. Without A, the answers from other companies vary less with some stakeholders but still, it is difficult to form one unified ecosystem. However, combining the surveys and interview data, we can form two categories of companies (B, C, D, G and E, F) for future research purposes.

The main result from the second survey is the position of a Refamo service provider. E and F manufacture items that are used by their customer and have strong research and development departments within their organizations. They are very interested in using the technology but would rather produce the service themselves to gain competitive advantage. The rest of the interviewees would use Refamo in items that are used to produce the offering for their customers. They would not directly gain competitive advantage with Refamo but potentially gain value in other ways. B did not place Refamo company in the ecosystem as they did not want to take a stand on the procurement of Refamo.

## 35.5 Discussion and Conclusions

The goal of this study was to get a wide understanding about possible benefits created by Refamo and the views on the sets of actors to form an ecosystem around the value proposition. The interviews were approached as a source of good qualitative data with two surveys to summarize the discussions and provide part of the results in quantitative form. Interviewee A did not consider themselves in central position within the Refamo ecosystem whereas all other interviewees did. As can be seen in Fig. 35.1, all but A are involved in the operation and maintenance phase of item's lifecycle. E and F are involved mainly by providing maintenance services to the machinery they have manufactured, thus they are shown to participate only halfway within the phase.

The companies that see themselves in central role within the ecosystem can be placed in two categories. The first category is companies B, C, D and G, who emphasize the operation and maintenance and disposal phases of the item's lifecycle where Refamo would be applied. They are open to getting Refamo services from an external service provider and are not seeking competitive advantage through Refamo but rather seek to reduce maintenance costs, costs related to lost production and increase the production time of their items. The most important benefits discussed with these companies were delaying new or re-investments, reducing production facility downtime due to both scheduled and unscheduled maintenance operations, and more accurate maintenance planning and organisation.

The second category is formed by companies E and F. They have monitoring and analytics capabilities within their organisation due to them producing high technology heavy machinery. They are engaged in a very competitive market and while they are clearly looking to gain competitive advantage by using Refamo, they would rather provide the service themselves to prevent competitors from gaining access to the benefits of Refamo. The most important benefits within this category were the feedback loop between product design and production, real usage data in real time for product design, usage data from end users, and optimisation of structures to for example make them lighter. The new ecosystems for each category are presented in Fig. 35.2. The stakeholders scored as 3 or better on average are positioned in the average position for each category.

When we consider the benefits within the life cycle of an item, we notice that both recognized categories of companies aim to prolong the operation and maintenance phase through the benefits and the second category looks to also shorten the first three phases of the lifecycle. This is expected since all interviewed companies, with the exception of A, create increasing amount of their revenue in the operation and maintenance phase. The most potential benefits within the Refamo ecosystem are the ones positioned in design and development, production, and operation and maintenance phases within the life cycle. The benefits positioned in other phases cannot be overlooked but based on our interviews; benefits in aforementioned phases are the potential ones. The set of actors to form an ecosystem to realize the value proposition of Refamo differs in the two categories of companies formed based on the interviews. In most answers, the key actors include the company of the interviewee, their customers, a supplier, company providing Refamo as a service, and university.

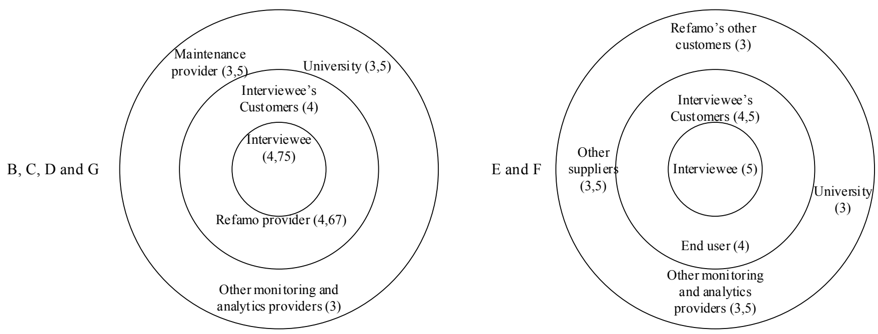


**Fig. 35.2** New Refamo ecosystems for each category

## 35.6 Limitations and Further Research

### *35.6.1 Limitations*

The interviewed companies did not currently have methods to accurately determine the remaining life of their items. The use of real time monitoring and analytics was very low as well. In general, they were very interested in the proposed system and could come up with benefits associated with it but since they have no experience from using such systems, there undoubtedly are still undiscovered benefits involved in using Refamo. Many of the interviewees pointed out some of their stakeholders that could in their opinion be even better ones to interview. In the scale of Refamo research project, the number of interviews were not increased from the initially planned ones. The industries our interviewees are part of differ very much. Some are very conservative, some in rapid growth and some very competitive. The same recognized benefit could create value in different ways depending on the company it is applied in, and for some companies it could be difficult to create any value even if the benefit is very clear.

### *35.6.2 Further Research*

The scope of this paper was to identify the potential benefits of using Refamo and recognizing the set of actors to form a new value creating Refamo ecosystem. The value created within the ecosystem considers the costs and risks associated in achieving the identified benefits. The value creation of using Refamo in an ecosystem is to be modelled in further research. It is also necessary to study how the created value is distributed between the actors of the Refamo ecosystem. The value created in an ecosystem should be distributed and used to improve the ecosystem, not just one key actor.

## Appendix 1. Interview Themes and Questions

**Theme 1: Product**

- Is managing the fatigue damage on a steel structure interesting?
- How real time fatigue monitoring (ReFaMo) could be used in items designed, manufactured and/or operated by your company?
- What other items could ReFaMo be used with?

**Theme 2: Data**

– What data do you gather related to steel structures?
– What new measurement data ReFaMo would bring to you and how is it compatible with your current measurement and analysis system?
– How should data ownership be considered within a service like ReFaMo?

**Theme 3: Value**

– What benefits and value ReFaMo could hold?
– What kind of decision making situations ReFaMo could be used in?
– How would you financially measure the value of ReFaMo?

**Theme 4: Business Model**

– Do you buy measurement and analysis services from external providers?
– How do you see the role of measurement and analysis services in future (in 2025) in your items and in your industry?

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