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Investigating and Evaluating Software Ecosystem Modelling in Practice in a Tier-2 Vehicle Telematics Company

Master's thesis in Software Engineering and Management

Chiara Lucatello & Monica Murgescu

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Abstract

Although different ecosystem modelling techniques exist, it is difficult to assess how used these are in practice among software companies. In this design science study, software ecosystem practices of a software company in the automotive domain were analysed; according to the findings, there are different perceptions of an ecosystem among management and developers, and there are no formalised modelling techniques being used in the company. The study was conducted in three iterations; in the following two iterations, two modelling techniques were analysed, identifying three different points of improvement for one of them. The technique for which the changes were proposed was the technique favoured by the participants of the study. The findings indicated that, while participants did not have a consistent view of which changes would provide more benefit to the modelling technique, many of them saw possible use cases for ecosystem modelling using the presented modelling technique. These use cases were consistent with the perceptions that the individuals had about software ecosystems and showed that they believed modelling techniques to be potentially useful for the company, even if they were not currently using them.

Keywords: software ecosystem, perceptions, collaboration, modelling techniques, software supply network diagram, unified modelling language, automotive industry disruptions

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Introduction

Attributing to the rise of digital transformation and new technologies, software industries are rapidly transforming and evolving (Yu & Deng, 2011). An extensive list of new possibilities have surfaced due to this digital revolution; for instance, cloud technologies, artificial intelligence, and the Internet of Things; these possibilities mean that companies not only require fundamental reorganisation, but also require ecosystem strategies to adopt these opportunities (Jansen, Cusumano, & Popp, 2019).

Traditional companies, such as the majority of those in the automotive industry, are currently undergoing their software-related transformation process due to four disruptions: sharing, electrification, connectivity, and automation (Kaiser, Stocker, & Fellmann, 2019). Original Equipment Manufacturers (OEMs) are consequently attempting to shape prospective ecosystems, and through standard-setting consortia have begun to widen their scope by including user-interface modelling, communication, and telematics (Lichtenstein, Dujmovic, & Baden-Fuller, 2018).

The adoption of new technologies leads organisations to rely on one another (Jansen et al., 2019), with this collaboration becoming a vital component to the success of the companies (Sadi & Yu, 2015). As organisations and software companies open their doors to other software companies and organisations, they learn that they become part of an ecosystem comprising of software companies, partners and developers (Van Den Berk, Jansen, & Luinenburg, 2010). Jansen et al. (2019) state that ecosystems are developed and nurtured, not created, as they are complex and dynamic systems which involve a large amount of differently motivated stakeholders.

The lack of practical information and practices for establishing ecosystems, the role of central design and standardisation, or research regarding an ecosystems life cycle leads organisations to reinvent methods and tools (Jansen et al., 2019). Software ecosystem modelling has several uses which can be classified into three parts: (1) it helps to gain insight and understanding of software ecosystems, (2) analysis of software ecosystems can be done through modelling, and (3) forecasting any development within the ecosystem based on future decisions is possible through software ecosystem modelling (Jansen, Handoyo, & Alves, 2015).

The need for modelling software ecosystems has become gradually more essential because (1) software suppliers have difficulties classifying and observing where they are active in distinct software ecosystems and (2) they face obstacles identifying their strategic advantage within these ecosystems (Boucharas, Jansen, & Brinkkem-

per, 2009). As stated by Jansen et al. (2015), modelling techniques and methods of visualisation currently exist, yet there is a lack of advancement towards understanding current practices for modelling software ecosystems, and by researching how to model ecosystems and their exchange of data, organisations and researchers would benefit when they examine and cultivate ecosystems. In addition, although existing modelling techniques have been studied, a limited number of studies analyse these techniques with real practitioners (Sadi & Yu, 2015). Designing software ecosystems can also be supported by further studying individual modelling techniques and by creating guidelines to group these together (Sadi & Yu, 2015). There is a need to advance upon a number of evolving issues in order for the field to mature. This is achieved by studying the key activities and areas of software ecosystems involving the managerial practices, architecture, and modelling (Jansen et al., 2015).

The purpose of the study may be divided into two connected parts. The first part is to investigate how software ecosystems are currently captured, documented, and shared within a software company. This first step, which was conducted in a company in the automotive field, aimed to establish how ecosystems are captured and recognised in a company within the software industry, and whether practitioners are aware of the techniques that are available to them when working with these ecosystems.

The second part involves a more practical approach, which is a continuation on the basis of the results given in the first part. Research shows that modelling supports the design of software ecosystems, facilitating the collaboration between partners in the ecosystem (Jansen et al., 2015; Sadi & Yu, 2015). Consequently, several modelling techniques within the same software ecosystem were tested at a software company to see if such techniques can help capture software ecosystems that fit organisational requirements for their specific implementation of the ecosystem.

Given that there is a present gap in the research when it comes to practitioners using modelling techniques in practice, the study presented an opportunity to bridge this gap by expanding on the existing techniques which are available to practitioners (Sadi & Yu, 2015).

By analysing current software ecosystem practices and testing several ecosystem modelling techniques within a software ecosystem, companies will be able to facilitate the adoption of software ecosystem practices and modelling techniques for their current and prospective software ecosystems. These potential improvements can be made by supporting modelling frameworks for shaping software ecosystems that can efficiently be used by practitioners in the company. The activities conducted by these practitioners (understanding the collaborators, their interactions, the activities performed, the different types of exchange relationships, and the characteristics of their collaboration, to name a few) are necessary for the company to be successful in a software ecosystem (Sadi & Yu, 2015).

The paper is organised as follows: Chapter 2 details the background research that went into the study, Chapter 3 presents the way in which the study was conducted, Chapter 4 outlines the results of the data analysis, results which are then discussed in Chapter 5, and finally, Chapter 6 summarises the content of the paper.

2

Background

This chapter presents an overview of literature that exists in both the field of (software) ecosystems, modelling software ecosystems, as well as the automotive domain.

2.1 An overview of how software ecosystems are developed, expanded, and modelled

2.1.1 Defining Software Ecosystems

Software industries outside of the automotive domain have been shifting their focus towards software ecosystems, thus also increasing the need for relevant research (Manikas & Hansen, 2013).

As the field of software ecosystem research is expanding, it has become difficult to maintain all relevant information and to keep up with all the new information and research within the domain (Jansen et al., 2015).

The concept of ecosystems stems from ecology, namely the notion of living organisms interacting as a community in union with non-living elements within their environment (Sidorov & Grinenko, 2013). Similar to biological ecosystems, software ecosystems possess the same essential characteristics and relationships within the software field as ecology possesses in nature (Jansen & Cusumano, 2012). Both have a limited amount of resources, dynamic changes within the ecosystem include or force out participants, and competition and collaboration occur within both ecosystems (Jansen & Cusumano, 2012). Although comparisons can be made, what differentiates participants in software ecosystems from those in biological ecosystems is the fact that the former can make an active decision to exit the ecosystem, or destroy it, which the latter cannot (Jansen & Cusumano, 2012).

There are various definitions for the term software ecosystems. Jansen and Cusumano (2012) constructed a definition based on the shared concepts defined their previous research, where the term is defined as:

> "A software ecosystem is a set of actors functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently underpinned by a common technological platform or market and operate through the exchange of information, resources and artifacts." (Jansen and Cusumano, 2012)

To streamline this definition at a higher degree of abstraction, software ecosystems are simply the set of organisations that are linked through software or software related components.

Sadi and Yu (2015) state the factors that create a successful ecosystem, which consist of a collaboration between the software development process, the platform on which the collaboration takes place, the interaction model between different organisations, and finally the business model that surrounds this ecosystem. Their paper lists practical requirements for describing software ecosystems and reviews certain modelling techniques, such as Software Supply Network Diagram (SSN), The i* Modelling Technique, Business Model Canvas (BMC), Value Network Diagram (VN), and e^{3}value Modelling (Sadi & Yu, 2015). The modelling techniques presented are the ones which have influenced the choice of modelling techniques used in this study as well.

2.1.2 Modelling Software Ecosystems

Software ecosystem modelling is one of the eight areas within the software ecosystem domain and has been prominently investigated (Barbosa & Alves, 2011). These areas include operating systems, software architecture, open source, software product line, business, software evolution, software co-innovation, and software ecosystem modelling (Barbosa & Alves, 2011). Modelling languages offer insight and facilitate assessments at various degrees, and although these models have significant overlap, each serves a distinct purpose (Jansen et al., 2019). These modelling languages in the field exist today, such as social-network, goal, and supply-chain models (Sadi & Yu, 2015).

According to Sadi and Yu (2015), the criteria encompassing these modelling techniques include that (1) the representation of software systems must use a modelling technique that is based on collected resources, (2) the relationships among the collaborators within the software ecosystem must be specifically modelled, and (3) thorough and extensive documentation, graphical/textual notation, syntax, and semantics must be incorporated in the modelling technique. Jansen et al. (2015) state that software ecosystem research is affected by a lack of a set of methods that are universally used in the field, as despite the availability of a number of visualisation and modelling techniques there are no explicit requirements for modelling software ecosystems.

Modelling language conventions can be interpreted differently depending on the individual who is doing the modelling, and these interpretations might not always be consistent among practitioners, even in the same field (van der Linden & Hoppenbrouwers, 2012). Language notation is meant to aid the modellers in creating an interpretation where the user can share an understanding of the model (Bork, Schrüffer, & Karagiannis, 2019).

In order to understand how software ecosystems are modelled and analysed, Jansen et al. (2019) provide a brief overview and insight on these areas. They state that models have a considerable overlap as they model the relationships, actors and software structures; however, each modelling technique and framework provides different

benefits and objectives. They also mention that monitoring an ecosystem over time can be challenging, as the growth of the ecosystem may become a complex process.

In an earlier work, Boucharas et al. (2009) present a formalised standard-setting approach for SSN in order to enhance the relationship and collaboration between companies, theorising weak links in a companys business model, and to anticipate forthcoming changes in the software ecosystem.

Yu and Deng (2011) apply the i* modelling technique in their study in order to help understand software ecosystems. Sidorov and Grinenko (2013) also approach software ecosystem modelling through the i* modelling technique, UML software ecosystem modelling, and Petri nets (Sidorov & Grinenko, 2013). In addition to these studies, Jansen et al. (2015) and Handoyo, Jansen, and Brinkkemper (2013) also mention that there is a prevalent need for improving modelling methods for organisations, and clarifies the reasoning behind modelling ecosystems, with proposed modelling techniques being (1) social networking models, (2) goal modelling languages like i*, and (3) supply chain networks. These sources portray the main modelling techniques that the software engineering literature has tried to apply to software ecosystems. As Sadi and Yu (2015) also highlight, despite the existence of literature on modelling techniques, there have not been enough studies on how companies apply these techniques in practice, or whether these techniques are successful.

Jansen et al. (2015) also state that there is a need to further research how modelling methods can be introduced and/or improved across organisations affected by rapid transformations, for example those operating in the automotive field trying to rethink their software ecosystems (Lichtenstein et al., 2018).

2.2 The impact of digitalisation and competing strategies within the automotive industry

In addition to the ecosystem modelling research which has been presented in Subsection 2.1.2, developments in the automotive domain are also relevant to the study, as the case company where the study is being conducted is part of this field, and developments in the field can have a direct impact on its ecosystem, and the ecosystem that it is part of.

In the automotive industry, prominent car manufacturers have extensively controlled both the hardware and software components within their architectural domain; they regulate over the division of labour and the division of revenue (Lichtenstein et al., 2018).

Naab, Rost, and Knodel (2018) directly state that there are disruptive changes in the automotive industry because of digitalisation, in particular software-based ecosystems. The example given was the case of Uber, which affected the traditional domain of the taxi business (Naab et al., 2018), which has been established in its earliest forms ever since the 15th century (Gilbey, 1903). This disruption has been facilitated by software platforms, which are often built and operated by the

ecosystem pioneers(s), which are the linking element between the various actors and their relationships inside the software ecosystem (Naab et al., 2018).

Due to these disruptions, automotive industry players are trying to adapt their business models and shape the ecosystems in which they operate, for example by gaining more knowledge to improve their systems (Lichtenstein et al., 2018). In terms of privacy and safety, the OEMs association policy is to allow third parties to access data exclusively via the OEMs where OEMs hold the responsibility for transferring such data (Lichtenstein et al., 2018). Data collection is considered one of the main ways in which knowledge can be attained, which is meant to facilitate an open software ecosystem, allowing multiple parties to use similar data collection techniques to provide their own services in the ecosystem; however, certain companies also choose to operate solely in a closed ecosystem (e.g. Tesla) (Lichtenstein et al., 2018).

Kaiser et al. (2019) also recognise the reorganisation which companies have started to undergo, with data and analytical services becoming the main product that they offer to customers, and with vehicle data being one of the main actors in the subsequent software ecosystems, or platform ecosystems. A prominent example of such a transformation is the Italian motor insurers working together with the automotive industry to provide telematics-based insurance (Kaiser et al., 2019). Vaia, Carmel, DeLone, Trautsch, and Menichetti (2012) present this case in detail and mention how the technology behind telematics (the technology that is responsible for compiling and transferring car data to relevant parties) is responsible for creating a new ecosystem within the automotive domain. Because many collaborators are being involved in this, OEMs have to move away from their traditional ways of thinking about software ecosystems in order to encapsulate new value and innovation, which creates opportunities for themselves and other players competing in the automotive domain (Vaia et al., 2012).

From the perspective of governing observers, predictions have been made where car industries shift "from hardware- to software-defined vehicles, which may also open up the software ecosystem in this industry" (Lichtenstein et al., 2018; Pelliccione et al., 2017). Vaia et al. (2012) identify that extending the software ecosystems (by including additional stakeholders such as technology and communication providers) enables value creation, as well as facilitating information sharing, which other industries also need to consider exploring as part of their digital transformation efforts.

There are three available transformation strategies listed by Lichtenstein et al. (2018) for software actors - inside and outside the ecosystem - to compete in the automotive space. These strategies revolve around the context of a *strategic bottleneck*.

Within the domain of software ecosystems, strategic bottlenecks are "a critical part of a technical system that has no - or very poor - alternatives at the present time" (Lichtenstein et al., 2018). Since the automotive manufacturers remain central and preeminent in the automotive domain regardless of the shifts in transformation, the strategies presented by Lichtenstein et al. (2018) suggest that (1) cooperation can be achieved between car manufacturers and innovators, (2) circumvent car manufacturers through the means of new digital platforms, or (3) attempt to evolve into becoming car manufacturers.

Provided that OEMs are striving to form future car software ecosystems for the connected aftermarket (Lichtenstein et al., 2018), further researching modelling practices and techniques within this domain could potentially aid in developing strategies for companies competing in the automotive sector's software ecosystem.

2.3 Case company

The company where the research was conducted was WirelessCar, a vehicle telematics company based primarily in Gothenburg, Sweden, formerly owned by Volvo Group. WirelessCar's works primarily with OEM car manufacturers to provide them with digital services (fleet management, position and journey services, vehicle status, remote diagnostic services, etc.) and connectivity to help them further digitalise their processes. The company is organised in different programmes, one for each customer with which they collaborate, as well as programmes that develop the general WirelessCar connectivity services. To conduct the research, permission was given by WirelessCar to analyse their ecosystems and collaborate with them in understanding the boundaries of this ecosystem, how it is captured, modelled, and what future value can be extracted from it.

3

Methods

This chapter focuses on the overall goals of the research, expressed through research questions, and also details about the design science approach that was employed.

3.1 Research questions

The following research questions have been formulated for this study:

RQ1 How are software ecosystems currently captured, documented, and shared in a software company within the automotive domain?

- RQ1.1 What perceptions do key players in the organization have in understanding the role of software ecosystems?
- RQ1.2 How do changes in the automotive domain influence how a company defines their software ecosystem?

RQ2 Which existing modelling techniques provide support in capturing software ecosystems at different levels of an organization within the automotive domain?

RQ3 In what way can an existing modelling technique be improved or adapted following company use cases?

- RQ3.1 What possible use cases does the company find for this modelling technique?

Through RQ1, the goal is to understand how a software company recognises software ecosystems across the hierarchical levels and across different roles within an organisation. This overall goal is divided into two sub-research questions: RQ1.1, which aims to understand whether a uniform perception of software ecosystems exists within the company as a baseline for the study; and RQ1.2, which focuses on the context in which an ecosystem is defined by the company, influenced by the disruptions in the automotive domain. The study would therefore present the opportunity to understand whether these disruptions are present in the company, and whether this is reflected in their perception of the software ecosystem(s).

RQ2 looks into modelling techniques as a way to support the capturing and representation of software ecosystems, and whether they are relevant in providing new information about software ecosystems to the case company.

RQ3 focuses on producing a tangible improvement to one software ecosystem modelling technique that is present in literature, in the context of the company where the study is being conducted. Its sub question intends to go more into depth about this topic and see practical aspects of using this improvement in the given company.

3.2 The Design Methods and Procedures

The study was conducted using a design science approach. Design science is a methodological approach to conduct a study, which aims at producing an artefact that solves a series of business needs (Wieringa, 2009). Hevner, March, Park, and Ram (2004) define a set of guidelines for conducting design science research, which state that the artefact has to be viable and relevant to the business problem, evaluated through rigorous and verifiable methods, resulting in relevant knowledge that can contribute to the knowledge base.

Peffers, Tuunanen, Rothenberger, and Chatterjee (2007) propose six activities for conducting design science research: (1) problem identification and motivation, (2) objectives of a solution, (3) design and development, (4) demonstration, (5) evaluation and (6) communication.

The study was divided into a number of iterations, each following the steps that have been outlined above, which have been concentrated under preparation for the iteration (where the problem and the objectives are defined), data collection (used for the design and development), and data analysis (for demonstration and evaluation of a solution).

The last objective is focused on communicating the problem and why this is important by answering questions about what has happened, why this happened, whether the solution is is useful or not, what additional problems have been identified and how this solution can be further refined in additional iterations. The first iteration was followed by a presentation for the company, so that practitioners could understand the results of the iteration, ask questions, and provide feedback on what has been developed during the study. The next two iterations were meant to include a similar presentation communicating the findings back to the company, but the circumstances surrounding the COVID-19 pandemic prevented that from happening. Communication was thereafter continued only through emails and video calls, in case additional resources were needed from the company.

A total of 3 iterations were conducted during the duration of the study. The study was conducted between February and May, with the first two iterations taking approximately three months, and the last, shorter iteration taking two weeks, with the remaining time being used to compile the results together.

3.2.1 Iteration 1

The focus of Iteration 1 was on first understanding whether software ecosystem practices are employed in the case company. In concrete terms, this meant investigating how the case company perceives, captures, analyses and shares software ecosystems,

and what requirements play a role in these perceptions. After discussions with the company, it was decided that the study would focus on a specific disruption in the automotive industry: the emergence of car sharing technologies; and that all modelling and ecosystem investigation efforts would relate to this area as well. The result of this decision was that it became necessary to collect data related to this disruption, in preparation for future iterations.

3.2.1.1 Preparation

For this iteration it was decided that interviews would be used to collect data, as they provide a "richer and deeper description" (Runeson and Höst, 2009) for the study. Interviews allow for data to be analysed using sorting and categories, which is essential to design a solution, and to triangulate comparisons from different data sources. Selecting different roles and personalities for the interview ensure that the study has a qualitative attribute (Runeson & Höst, 2009).

The first step in preparing these interviews was creating the interview questions and running pilot tests, both with the academic supervisor overseeing the thesis, and with the company supervisor. Three different sets of interview questions were created based on the groups of participants (see Appendix A.1 for the three sets of interview questions). These groups were classified as: (1) internal developers, architects, and managers, (2) external stakeholders, and (3) car dealerships/rentals/manufacturers. The term 'internal' is used to describe the people who are working inside the case company, while 'external' means that they are part of a separate organisation, but are still members of the overall ecosystem. An additional step in preparing the interview questions was mapping them to the first research question (and its sub-research questions; see Appendix A.2), to ensure that all of the objectives of the iteration were covered.

The interview questions consisted of a general background section to understand the role of the interviewees in the company, followed by a number of questions on ecosystems and their perceptions of ecosystems, and then a final section related to the general understanding of the disruptions present in the automobile industry. The section on ecosystems considered both situations where participants were either aware or not aware of what a software ecosystem was. If the participant was not aware of an ecosystem, the subsequent questions focused on seeing if concepts related to ecosystems were familiar to them in broad terms. The last section was meant to provide a context for the following iteration, in particular when it comes to the examples that the participants are going to be modelling.

The selection of who would be participating in the study was left at the discretion of the company supervisor, who provided a number of contacts (architects, managers, external stakeholders), who then also referred to an additional number of developers and other company members who would be willing to participate in the study. Prior to the interviews and in order to ensure that the ethical implications of conducting the study aligned with the aforementioned elements referenced in Section 3.3, the interviewees were presented with a consent form asking them whether the interview could be recorded and assuring them that their anonymity would be preserved. Ad-

ditionally, the objectives of the study were disclosed and clarified to the interviewees. This assurance provided participants a level of comfort and a significant degree of trust within the interview environment.

3.2.1.2 Data Collection

During this iteration, data was collected using semi-structured interviews, with each interview lasting between 25 minutes and 35 minutes. As the interviews were semi-structured, this allowed the interviewees to have a conversation-like session, and additional areas of interest, which had not been initially considered, could be explored organically (Runeson & Höst, 2009). A total of eight interviews were conducted with key players within the company and the external stakeholders. These included two developers, two architects, two managers, and two external stakeholders (one working for an automobile OEM, and another working in a car dealership). Consent forms were signed by the participants (one copy for the participant, one copy for the interviewers), and all participants consented to the recording of their interviews, which simplified the subsequent data analysis. Notes were also taken throughout the interview.

All interviews were conducted in English, in person, at the company headquarters, and in private rooms to prevent any external disturbances from distracting the interviewees. An exception was made for the participants who are not working at the case company: one interview was conducted over Skype (because the interviewee was located in another country), and the other one took place in an office at a car dealership. The consent form assuring their anonymity and the confidentiality of the information given, along with conducting the interview in a familiar setting, created a comfortable environment for the participants. During the interviews, one person was tasked with being the main interviewer and asking all the questions, while another person took notes on the key points that were discovered.

During the interview with the first participant, the subject asked for examples of ecosystems and modelling techniques. This indicated a need for better preparation for the following interviews, considering that a revision to the interview questions would not have been sufficient to express the concepts in a more understandable way for the participant. This led to the creation of a short presentation with examples of different software ecosystems modelled using various techniques. The possible biasing of participants for future iterations was considered in this approach, so the presentation was created to present the information in the most neutral method possible. The models were exclusively visual representations extracted from literature, with no further textual explanations or emphasis on specific parts of the model. This presentation was shown to participants only when they asked for a clarification on what a software ecosystem was.

3.2.1.3 Data Analysis

With all of the interviews recorded, the second step was transcribing all of the interviews into text. This resulted in over 50 pages of text to be analysed. The analysis was done using thematic coding (Saldaña, 2015). Notes taken during the

interviews were used to supplement the transcriptions and ensure their correctness in case the audio quality of the recording was lower than expected.

The analysis was conducted at two different levels of formalism. This included a *template approach* combined with an *editing approach* (Runeson & Höst, 2009). A template approach included more a priori based on the interview questions, respectively mapped to each research question referenced (see Appendix A.2. The editing approach allowed for codes to be defined based on the findings obtained in each interview. A combination of these two approaches allowed the qualitative analysis to be structured towards a clear chain of evidence.

The results were first analysed individually by each researcher in order to mitigate any bias that may arise from each researcher's own perception Runeson and Höst (2009). The results of this process were then combined into a single summary, with discussions taking place to ensure that the results were consistent in the rare case where it was needed, and relevant quotes were extracted from the interviews to support each theme discovered. The anonymized results were presented to both the academic and the company supervisor as soon as they were complete.

3.2.2 Iteration 2

After understanding software ecosystem practices in the case company, the second iteration was focused more on understanding whether modelling techniques defined in literature can assist in modelling a software ecosystem in practice. This included the collaboration between key players within the ecosystem, as well as a further understanding of whether existing modelling techniques can help capture software ecosystems across various levels of an organisation.

3.2.2.1 Preparation

Based on the mapped interview questions presented in Appendix A.2 and after extracting the responses that align with the different aspects of ecosystems (perceptions, capturing, documenting), as well as stakeholder awareness and the impacts of the automotive industry transformation, two main views were discovered. One is a more technical view including both internal and external stakeholders, and the second one is as a high-level view of the software ecosystem primarily focusing on external stakeholders. These two views were then cross-examined with existing literature to identify modelling techniques that could suitably fulfil the respondents' expectations for ecosystem modelling, with two techniques being deemed fit for this task: Software Supply Network (SSN) Diagrams and Unified Modelling Language (UML) Class Diagrams. More details about this choice are presented in Section 4.2.

Initially, a number of focus groups and workshops were planned for the study. Focus groups were chosen as a way to present different modelling techniques to the participants, and as an initial way to collect feedback on the techniques chosen, as well as to be able to answer any questions regarding these techniques. After that, workshops would have been conducted, in which workshop participants could use these techniques to model a software ecosystem relevant to their programme. The

resulting ecosystems, and the difficulties that the participants encountered during their modelling section would have constituted the main data to be analysed during this iteration. The aim was to conduct 2 focus groups and 2 workshops involving a number participants with different roles in the company.

However, due to the COVID-19 pandemic that took place in the Spring of 2020, it became apparent that gathering people in the same room for an extended time, in which they must interact and work together, might be socially irresponsible for everyone involved. As a result, the workshops and focus groups had to be conducted online. To facilitate this, a web page was created, with the dual purpose of presenting the chosen modelling techniques to the participants and providing them with a space to test out these modelling techniques independently. See Appendix B.2 for a view of this page.

3.2.2.2 Data Collection

To facilitate this online component of the study, two videos were created presenting the SSN and UML modelling techniques, including explanations about what they are used for, a presentation of their main components, as well as an introduction to the tools that would be used for the modelling exercise. These were put on a web page, alongside a task explanation asking participants to choose between the two techniques, as well as to model the section of the company that they are working in using one of the techniques, followed by a short survey about their experience using the modelling technique.

The short survey comprised of eight questions which were focused on three main points for the study. Three free-text answers allowed respondents to give information, their opinions, and to provide them with an opportunity to explain their reasoning further. The five remaining questions were based on a 5-point Likert scale with responses ranging from 'strongly disagree' to 'agree', and from 'difficult to use' to 'very easy to use'. The full list of survey questions can be seen in Appendix B.1.

The web page used an embedded draw.io[1] element, which was preset with custom libraries for both UML and SSN, allowing participants to create their models directly on the usability study page. The resulting page was hosted on Google Firebase's free plan to allow for an easy way to distribute it to individuals within the company.

In mid-April, the online ecosystem usability study was sent to a programme manager within one of the customer programmes at WirelessCar. The programme manager then sent the online usability study to those who might be interested in taking part in the study, as employees were asked to work from home due to the COVID-19 pandemic. Considering that many people were working from home, a convenience sampling method was selected to collect data for this iteration, as it was the most practical perspective based on time and location (Etikan, Musa, & Alkassim, 2016). This convenience sampling resulted in approximately 10 individuals being asked to complete the study within the chosen programme. After two weeks, the online usability study was extended out to another six other individuals in the company,

[1] https://github.com/jgraph/drawio-integration

using the same convenience sampling method. The usability study was concluded in the first week of May, with a total of six responses comprising of four developers, one architect, and one programme manager, resulting in a total response rate of 37.5%.

3.2.2.3 Data Analysis

The results of the survey, along with the models created by the participants which were submitted through the usability study page, were stored in Google Firebase's Realtime Database as JSON objects representing each response (pairs of question and answer strings, together with Base64-encoded images for the models). As every response was stored separately, the first step in analysing the data was to combine the data according to each question and to create graphs to be able to visualise the Likert scale responses.

To analyse the results, each researcher conducted their own code analysis, and then the resulting codes were merged after discussing them and reaching consensus. The answers to the questions were then split into three thematic points using the *editing approach* (Runeson & Höst, 2009). These thematic codes were discovered as part of the findings of the current iteration. Subsequently, the responses and the resulting diagrams, were broken down between the two modelling techniques, depending on which modelling technique each participant chose favourable for the exercise. Finally, a summary of the responses was created for each data point, which included information from responses derived from the modelling technique they chose, with the focus being on understanding what each participant prioritised when using each technique, and how well they considered each technique to work in the specified context.

3.2.3 Iteration 3

The focus of Iteration 3 was on refining the practices that were evaluated during Iteration 2, and on understanding how these modelling techniques can be potentially improved to provide the case company with a better understanding of capturing software ecosystems.

3.2.3.1 Preparation

After analysing the results of Iteration 2, an assessment was made on which parts of the modelling techniques were considered beneficial by the participants, and which were not useful in capturing ecosystems. During Iteration 2, two modelling techniques (SSN and UML) were evaluated; for this iteration the focus was solely on SSN, based on the findings of the individuals who used both modelling techniques.

Due to difficulties in collecting responses for Iteration 2 tied to the time needed for participants to complete the usability study, a more streamlined research instrument was selected for this iteration of the study. Three potential changes to SSN were compiled as a result of the previous iteration's analysis and proposed to subjects as possible improvements to the modelling technique.

3.2.3.2 Data Collection

Data collection for this iteration was done through the form of a 10-question survey. A survey was more suitable for this iteration due to the circumstances surrounding COVID-19. This method allowed for the distribution of the survey to people in the company who are working from home, and the short nature of the questions would allow respondents to quickly provide their feedback (Runeson & Höst, 2009).

The survey was done using Google Forms and sent out to the company supervisor to be distributed among members of the company. The survey was divided into sections, with each improvement having one Likert scale question about how useful the improvement is, ranging from 'not very useful' to 'very useful', and with the option of explaining their thought process behind this assessment. Finally, participants were asked to select the improvement which they favoured between the three, suggest a number of additional improvements (formulated as an open question), and asked to select from a multiple-choice list of possible use cases where they believe these models could be used in the company. For the purpose of this study, the focus was on identifying at least one change which could be useful for modelling ecosystems for current and prospective company use cases. The survey instrument can be viewed in Appendix C.1.

The survey was sent out to the same individuals who had completed the usability study in Iteration 2, followed by another number of individuals suggested by the company advisor, resulting in a convenience sampling of participants. Out of the approximately 18 people who had been contacted, seven participants responded to the survey, for a 38.8% response rate.

3.2.3.3 Data Analysis

The first step in analysing the data was exporting the survey answers into an Excel sheet. The use of Google Forms for this instrument allowed the Likert scale answers to be presented in bar charts in the Google Forms responses section, so no additional steps were necessary to compile this part of the results. These charts and the answers to the remaining questions were analysed using several steps of quantitative analysis presented by Bell, Bryman, and Harley (2018):

1) Transforming the responses into data. For the Likert scale responses, bar graphs with their corresponding number were generated through Google Forms.
2) Quantifying the Likert scale responses and mapping them to their additional short answer responses based on each change model, followed by cross-referencing their responses to the overall assessment of all three changes (Question 7 and 9 in the survey). See Appendix C.1.
3) Interpreting the results of the analysis and connecting the findings extracted from the results.
4) The open-ended questions representing the qualitative data were also collected together and summarised using an editing approach, as outlined by Runeson and Höst (2009), with a comparison of the responses to the perceptions identified during the first iteration. This was done by grouping questions according

to their alignment with the core themes which help to answer the research questions. The resulting groupings were broken down into three sections: usefulness assessment for each individual change, assessment of overall model improvement, and prospective use cases for ecosystem modelling in the case company.

3.3 Ethical issues in the study

The following sub-sections outline the limitations and safeguards of the study in regards to ethics and ethical behaviour in the field of software engineering (Andrews & Pradhan, 2001).

3.3.1 Trust with information and regulatory compliance

In accordance with university policies, the researchers chose an academic supervisor to supervise the study. The supervisor chosen is familiar with the theoretical and practical concepts of the research and is responsible for academically guiding the researchers in accordance to university requirements for the study. To safeguard the information that was disclosed to the researchers, the researchers were asked to sign a non-disclosure agreement constructing the boundaries of the study and the operations of the study.

In order to monitor and enforce this agreement, a company supervisor was assigned to the researchers where constant communication was documented and maintained by the researchers and company supervisor. Any concerns brought up by the company supervisor during the study were mitigated or clarified through weekly reports, bi-weekly presentations, and remote online meetings whenever necessary.

Any information gained in the study was properly disclosed by the researchers to the company supervisor and relevant parties involved in the study including the academic supervisor. In terms of the information disclosed in this report, the company is responsible for concisely outlining any information which must be excluded in the study.

Prior to data collection, it was imperative for the main parties to meet in order to avoid any misinterpretations of the study from both the company and the academic side. This meeting involved the researchers, the academic supervisor, and the company supervisor. Any concerns, questions, and limitations of the study were addressed during this meeting. In the event that the study is published, whether the identity of the case company is revealed in the resulting paper or not remains at the discretion of the case company itself.

3.3.2 Ethical issues in data collection

The anonymity centred in the data collection methods ensures that the participants/individuals in the study remain undisclosed. This is present in Chapter 4 where direct quotes extracted from the interviews and surveys are kept anonymous.

According to Coffelt (2017), confidentiality in the study implies that the researcher knows the identity of the participant(s); this is usually evident during an interview. The researchers are aware of the participant, their name, and any underlying information that centres around the participant's identity. The researchers of the study are responsible for protecting the identities of each participant revealed during the interviews. The researchers are liable to the information provided by each participant and it is their responsibility to mask any liable information and only disclose any relevant information to the study.

The participants of the study were made aware of their confidentiality and anonymity through consent forms presented to them prior to proceeding with data collection. The participants were then asked to sign the form and check a number of boxes confirming the following points: (1) their understanding of the procedures outlined in the consent form and their agreement to participate in the study, (2) the acknowledgement that the data collected would remain confidential and anonymous, (3) the permission for the interview to be recorded, and (4) the permission to use their direct quotes that fit into context for the study while ensuring anonymity and confidentiality.

When surveys were used in data collection (both Iteration 2 and Iteration 3), the participants were similarly promised that their answers would be anonymous and confidential. No personally-identifiable data was asked in the surveys and, as these were conducted online, the researchers were also unaware of the identities of the participants.

3.4 Threats to validity

In order to ensure that the outcome of the study is valid and relevant to the field, a number of threats to validity were considered which could impact the credibility of the research. The three areas which pose the most threats are those related to construct, external, and internal validity.

3.4.1 Construct validity

A number of threats to construct validity were identified, which deals with the way in which the construct is interpreted by the different parties (Wohlin et al., 2012). In the case of this study there is the risk that the interpretations of the materials during the interview might be misinterpreted by the interviewer or by the interviewee, resulting in another threat in construct validity. Misinterpretation can lead to the collection of information that is inconsistent to fit the respective questions asked during the interview. In order to mitigate this threat, the interviews were conducted in a semi-structured way, which allowed for discussions to flow freely, and for the interviewees to ask for clarifications if it was needed, or for the interviewers to ask additional questions. One of the main points considered was that the subjects could misunderstand modelling constructs, therefore the possibility of follow-up questions was kept in mind during the analysis stage.

The main threat while conducting interviews during Iteration 1 was that different interview protocols were applied to members with different roles in the company and outside of the company, based on their respective position. This threat was acknowledged, and the different sets of questions were focused more on identifying information that was specific to the position held by the interviewee. Most of the base questions related to how ecosystems are captured and how the collaboration is performed were the same, but each participant had the opportunity to more deeply explore the domain in which they were more familiar.

One threat that was identified during Iteration 2 was the risk of biasing participants towards a specific modelling technique due to the manner in which the data collection was conducted. The participants were presented with two pre-selected modelling techniques based on the results from Iteration 1, and videos were used to explain the fundamentals of these modelling techniques. To mitigate the risk of biasing them from the beginning, the videos were made to be the same length and have the same structure, so that participants would not perceive one technique as being favoured over the other.

3.4.2 Internal validity

There are a number of possible threats to internal validity related to the way in which the artefacts are evaluated during the evaluation phase. One example is instrumentation, where the data collection methods are designed in such a way that they affect the result of the analysis (Wohlin et al., 2012). To prevent this as much as possible, all of the material was presented to the academic supervisor before being applied to the subjects. This included all of the sets of interview questions, as well as the proposed modelling workshops.

To improve the reliability of the interview and survey instruments, both of these were piloted before being presented to the participants in the company. The interview questions for the first iteration were piloted alongside two product managers at the case company. After reviewing the interview questions, they were then sent to the academic supervisor for further revision. The survey instruments for the second and third iteration were first reviewed by the academic supervisor, and also by individuals from the University of Gothenburg who had no prior knowledge of the assessed techniques ensuring that the questions were clear and comprehensible to people with a variety of experience in ecosystem modelling (from no experience, to being familiar with the models).

Another point of concern during the analysis process was the risk that the analysed interview data would be biased by the researchers' own notions on the presented information. Following the guidelines by Runeson and Höst (2009), the analysis was conducted individually by each researcher, followed by the collection of the results into a single summary (see Sub-subsection 3.2.1.3 for the full analysis procedure). The method of separating the analysis and following different levels of formalism ensured that the validity of the study would be increased (Runeson & Höst, 2009).

Another threat would be that the artefacts proposed here, which are believed to aid in solving the problems identified in the company, actually have side effects which

negatively impact their processes. For example, introducing a modelling technique where there were none before may create an additional amount of work, slowing down the process more than helping it. The main way this could be prevented is by being aware of the possible implications that introducing a new solution brings, and making sure that these are evaluated accordingly.

One additional limitation was the time frame in which the study had to be conducted. The 5-month period of the study limited the amount of data that could be collected; in addition, a number of factors posed limitations on what instruments could be applied, and on the amount of iterations that could be conducted. This made it more important to ensure that every iteration was conducted in a way which could provide an adequate amount of data and a suitable solution. This process was also affected by the COVID-19 pandemic, influencing operations in the case company to a significant degree, with many people in the company being laid off or working from home. This created difficulties in reaching out to people to collect data.

3.4.3 External validity

The main threat to external validity is that the results of the investigation cannot be generalised outside of the case company (Runeson & Höst, 2009). Given that the company is involved with a number of different actors, the study has collected data from both inside and outside of the company. This was meant to help mitigate this risk to the validity of the study, by ensuring that there is consistency in the views and the data sources for the analysis. Whether this can be generalised to other companies in the automotive domain will be discussed in the Discussion section (see Chapter 5).

4

Results

This section covers the analysis results of the study, presenting the processed data that has emerged and the design science artefacts that have been created. The data collected and presented in this section was related to a number of areas necessary to answer the RQs: how software ecosystems are currently captured and represented in the company, how the company collaborates to enable ecosystem knowledge sharing, factors that might affect the resulting models, and an assessment of modelling techniques themselves. The rationale behind this was that to be able to understand the way the company perceives and uses modelling techniques, it was necessary to first assess what the organisational culture is like, while keeping a general focus on ecosystems. Finally, understanding business practices allowed for a better awareness of what the company would like to focus on concerning their software ecosystem. At the same time, it allowed the researchers to better choose a modelling technique that could represent their relationships with their business partners and the changes that the company is going through, due to their unique relationship with OEMs and the automotive domain disruptions.

4.1 Company Perceptions and Understanding of Software Ecosystems

As outlined in Sub-subsection 3.2.1.3, the interviews of the first iteration were broken down into a number of themes. This resulted in four main themes, with a total of 7 sub-themes, and 152 quotes to support the discovered themes. A summary of the breakdown between the themes and sub-themes is presented in Table 4.1, and each of the themes has also been briefly explained and exemplified below. The main themes were subdivided based on respondent answers to the overlapping interview question, and then mapping these by the corresponding research question(s) (please refer to Appendix A.2 for this mapping). All of the quotes presented in this chapter were made anonymous when needed, and are attributed only to the position of the participant; a full list of all collected quotes can be found in Appendix A.3.

4.1.1 Perceptions of SECO

The results in this sections answer *RQ1.1 What perceptions do key players in the organization have in understanding the role of software ecosystems?*

Table 4.1: Themes and sub-themes discovered during the analysis

Theme	Sub-theme
Perceptions of SECO	Understanding Software Ecosystems Perceptions of Software Ecosystems Stakeholder Awareness
Sharing of SECO	Documenting/Guidelines of Software Ecosystems Sharing Software Ecosystems
Collaboration	-
Defining SECO	Impact of Automotive Transformation Process Focusing business decisions for the connected aftermarket

Understanding Software Ecosystems

The aim for this theme was to discover whether the interviewees understood the term "software ecosystem" and to comprehend their definition of software ecosystem. The main focus was to establish whether participants were aware of the term and, if not, provide them with a definition presented by Jansen and Cusumano (2012) (see Chapter 2), used as a starting point for the study. Some of the respondents mentioned that they are familiar with the term, others mentioned technical aspects that could define an ecosystem. A selection of these answers is presented below:

> "It could be like ecosystems in the sense of making software, developing it, how it goes around, but it could mean a lot of things. it's so subjective." (Software Developer)

> "Yes, I think so. If you mean more or less frameworks and such. Frameworks and yeah." (Architect)

> "A bit. Then you need to enlighten me. So in terms how companies are working together, for some years ago everyone was providing their own platforms...But by providing isolated services you really decouple technology and you can bring in co-creation together with others. So, this is why we provide services to our customers and they are the makers of the connected car platforms. So, we see how different partners in the ecosystem provide software, is it as a product, is it as a service, and who is the owner of the roadmap." (Product Manager)

> "Familiar, well yes, but not so in deep. It is a very fluffy word that can mean a lot of things." (Product Manager)

The responses presented above indicate that individuals had different interpretations when defining software ecosystems. All interviewees asked the researchers to define software ecosystems in order to gain a better understanding. The comprehension of software ecosystems is a subjective topic among individuals, but many also mentioned that they have a passing familiarity with the concept.

Perception of Software Ecosystems

This theme looks into how different actors view the idea of a software ecosystem in the company, team, or programme, and whether there are consistent interpretations among people in similar positions and across different teams. This is different from the "Understanding" of Software Ecosystems, which focuses more on the term itself, while "Perception" focuses on the way software ecosystems are regarded and interpreted based on the individual.

Among the software developers, perceptions of software ecosystems are based on each individual and the roles they have within the company.

> "when you see those diagrams and when you see the documentation you might know what they are, but you might not know how they are functioning internally..." (Software Developer)
>
> "So it's very hard to actually bring everyone under one umbrella. But if that was the case, things would have been very nice." (Software Developer)
>
> "I think so, yeah. I mean, I cannot speak from the point of view of the people who work closer with the customer" (Software Developer).

According to architects, software ecosystems are perceived to be more technical; they believe this knowledge is spread out amongst the minds of individuals in the company.

> "we mostly work in the Java domain, Java language, and I mean, that's a very solid knowledge in teams, but the Java ecosystems of frameworks and tools, if I interpret the ecosystem as the frameworks and tools." (Architect)
>
> "so it's very much in the heads of many people, but it's spread out among of many people." (Architect)

Managers have a better understanding of software ecosystems that align with the definition provided by Jansen and Cusumano (2012). They have a general overview of the external stakeholders involved.

> "So in that sense we are partners in creation with the customer. And in some cases we are also covering partners intelligence in everything, so it's everything." (Product Manager)

When validating these results during the regular meetings with the company supervisor and relevant parties internal to the company, another perception was collected, in addition to the data that had already been analysed. A product manager expressed surprise at the fact that there was an ecosystem inside the company, as they had assumed that the ecosystem is primarily defined by the outside stakeholders, but not between the different teams in the company. Further discussions during the meeting revealed that that view was shared among other members of management.

Stakeholder awareness

Given that stakeholders are a key part in software ecosystems, this theme collects all of the information related to these actors, both internally and externally. The

questions posed to the interviewees aimed to understand whether they are aware of the various stakeholders working with the company, both internally and externally, and how these relationships affect the software ecosystem. The resulting analysis showed that the stakeholders are very present in the decision-making process by participating in regular planning meetings every couple of months. The interviewees were asked about their views both on internal stakeholders and external stakeholders. All interviewees recognised the main stakeholder for each programme as the customer (the OEM) that is associated with each specific programme. They also identified certain parts of the organisation as functioning as internal stakeholders for other parts of the organisation.

> "independent depending on the programme, so we have internal stakeholders, I mean we have in the delivery organization we have defined roles, responsibilities that work with the external, and we also have sales and marketing and they have their stakeholders at the customers. So, it differs with what role you have." (Product Manager)

When asked about external stakeholders, different types of stakeholders were mentioned, from major tech companies, research partners (automotive safety or driver behaviour), as well as ecosystem partners with whom the company does not work directly.

> "all the impact. I mean, they decide everything, right? They are the stakeholders." (Software Developer)

> "We also have external stakeholders within the Wireless programme, also, for example TechLab, from the top floor, we use things from them, so that ends up having, that ends up making them some sort of an external stakeholder, but they are still within Wireless" (Software Developer).

> "we work with [telecommunications company], which is an ecosystem partner, we don't develop anything together, but we see that we are integrated with each other, so they can actually broadcast the services in China" (Product Manager).

Stakeholder awareness could be divided into external and internal awareness of the various stakeholders which are present in the company. One of the main points was that the same stakeholder could be viewed as internal to some of the people who were interviewed, but external to others, depending on their own position and programme in the company.

Perceptions encapsulated

The main idea of each of the three preceding themes can be summarised in one sentence: perceptions among members of the company are not consistent. Developers perceive external stakeholders to include other programmes within the company (TechLab), a view which differs from managerial perspectives where external stakeholders exist outside the boundaries of the company. Depending on the role individuals have in the company, their perceptions vary quite significantly. A few managers do not believe that an internal software ecosystem exists within the company, while

developers and architects perceive that internal software ecosystems exist across different areas within the company, because they have different definitions of what a software ecosystem is. One similarity that stems across all interviewees inside the company is the awareness that OEMs are the main stakeholders.

4.1.2 Sharing of SECO

This theme helps to answer *RQ1. How are software ecosystems currently captured, documented, and shared in a software company within the automotive domain?*, by looking in particular at how the case company shares knowledge and understanding pertaining to the ecosystem in which they operate. This is also influenced by each individual perception, as the previous section shows that this is dependent on each person's role in the company.

Documenting/Guidelines of Software Ecosystems

This theme is looking specifically into diagrams, models, written documentation that presents the software ecosystem. As some of the interview subjects were not familiar with the term software ecosystem, some of the questions were formulated in a much broader manner, such as asking about the collaboration between actors.

This resulted in a lot of information about the documentation practices in the company in general, which should also apply when it comes to software ecosystems. For example, the importance of documentation was noticed by all the subjects interviewed inside of the company. The need for documentation has also been noticed by members of the development team, in particular when new people join the team, but where documentation exists, this is presented in an accessible way for those with both high and low technical knowledge. However, there is a need for coherent documentation that is understood by individuals across all programmes. A preference for visual presentation of information was also noted.

> "And its vital for us to document all of this because if for example, if someone new joins our team or the Wireless programme in general, they must know how we are collaborating with them." (Software Developer)
>
> "we have always meeting notes, with all decisions and topics and everything that we have discussed" (Architect)
>
> "there is one thing that we may lack at WirelessCar, that is documentation and processes written, we have good enough, but it's not too easy to take part of other programmes." (Product Manager)
>
> "my preference is that I like the visual presentation and information because it's easier to quicker understand and get a higher understanding. So I think that is absolutely. I think that is a good thing. And also when you are new, you come in a new programme it really, really helps to quicker get efficient and start to work if you understand the interfaces and the way of working. So yes, absolutely." (Product Manager)

When asked if the software ecosystem itself is modelled or not, everyone answered

according to their own perceptions. Developers and architects recognised that there are multiple technical diagrams, but when asked whether there is a diagram outlining the relevant stakeholders pertaining to their specific team, programme or operation, they were unaware of whether such a diagram existed or not. Product managers answered that there are technical diagrams in which they list their customer interfaces, especially for the larger customer programmes, and also that they have a diagram describing the ecosystem, including in particular which partners they collaborate with.

> "Definitely not, no. Or at least I am not aware of them." (Software Developer)

> "Technical diagrams, how we interact, our components [...] Yeah, of course, yeah, of course." (Software Developer)

> "Not as an organisation chart or something. We have just our interfaces listed. In our case its so different because Volkswagen is a huge programme and they have so many customer interfaces, I think they actually have that, what you are describing." (Product Manager)

Sharing Software Ecosystems

With this theme, the goal was to specifically look into the way in which knowledge is shared among teams and inside the company, particularly knowledge that could pertain to software ecosystems (including collaborations, relationships, stakeholders, etc). This theme is closely connected to the documentation/guidelines theme, but whereas the former was focused more on practical representations, the latter attempts to extract information on the processes used to share ecosystems.

One of the main points stated among the interviewees stressed the importance of communication and the role it plays within the company. Communication between team members is mentioned to be essential across all organisational levels within the company. Respondents noticed the that even when documentation is absent, there is usually at least one person who they can talk to in order to acquire the information they are seeking.

> "...the communication between the team members is very helpful there. So some knowledge still remains tacit, it passes from word to word, but it sometimes never lands up in the documentation, so for me I had to rely both on the documentation and people making me understand some things." (Software Developer)

Multiple respondents also mention regular stand-up meetings as an integral way to foster communication and knowledge sharing. Based on the interviews with participants, it was noted that teams work in an agile development process using the Scrum framework. Teams have regular stand-up meetings in the mornings, sprint planning meetings, retrospective meetings, and even their own informal "lunch talks" when knowledge needs to be shared company-wide. Meetings for the architectural leads also occur among architects, in which they discuss future technology in the ecosystem.

> "we usually have Slack channels where we have everyone together and its open and public and everybody can see what's going on" (Software Developer)

> "Mainly through programme stand-ups where all the teams get together, go through major changes in the ecosystem. And then we have the WirelessCar architecture meeting where all the lead solution architects gather to discuss future technology in the ecosystem, what to use." (Architect)

> "if we see that we need, oh we need to have maybe a lunch talk to spread the information we set up that up at WirelessCar so everyone can know. So, we really try to see how is the best way to reach out to this kind of knowledge sharing." (Product Manager).

Despite the multiple channels of communication between individuals, both formal and informal, knowledge sharing is still considered a challenge. One example of such a challenge is that not all knowledge is shared equally, which affects the amount of information someone would have to work with.

> "a challenge, but we always try to share that knowledge" (Project Manager)

> "When you are a developer sitting in a team you don't have as much information actually and the world gets smaller. So I think it would be really good if you could visualize that, because then it's accessible for everybody." (Product Manager)

Sharing Encapsulated

The two themes that have been presented have a common theme: a strong focus on communication, which can be enhanced through consistent documentation practices. Although not all interviewees could answer questions pertaining specifically to software ecosystems, both of these aspects remain important. Perceptions among different company roles remain one differentiating factor in the type of documentation that respondents talked about, but less so when it came to other types of knowledge sharing.

> "this is actually the most important thing with WirelessCar, to build this common understanding and knowledge and competence on how do we build connected services in the best way, and we use that in all programmes, and at the same time manage to do the customisation. That creates really strong ecosystem or solution." (Project Manager)

At the same time, product managers spoke of the need to create common understanding, which also leads to a strong ecosystem, concept which is exemplified in the above quote. The company is continuously undergoing a transformation process and is focusing on having a prevalent awareness of its ecosystems. Disruptions in the automotive domain regarding car sharing and connected services has been an area that has impacted the way this transformation process is shifting.

4.1.3 Collaboration

This theme helps to answer *RQ1. How are software ecosystems currently captured, documented, and shared in a software company within the automotive domain?* One of the main points of this theme was understanding how different programmes and different teams within the programme work together with one another. For context, the company is organised into customer programmes, each with its own development process and teams working together, although a number of sections develop common services for the rest of the programmes.

The previous section outlines the importance of communication between team members, and how that is useful in sharing knowledge about ecosystems. This theme aims to investigate this knowledge sharing on a higher level of abstraction, given that communication was prevalent among teams. The focus is placed on understanding how collaboration emerges across all layers of the company in order to see if inter-company collaboration fosters communication that aligns with ecosystem knowledge sharing.

Based on the results derived from the interviews, it was noted that each programme within the company is independent from each other. The exception to this are the programmes which develop common services, and which end up collaborating with all of the individual customer programmes. On the programme level, each programme is free to decide its own working process. However, multiple answers point out that there is a push towards harmonising these different ways of working, both when it comes to technical infrastructure and work-process (such as a working model) or having similar ways of defining the definition of done, and other aspects.

Nevertheless, developers feel that tight collaboration exists inside the company and individuals are aware of who to speak with regardless of what team they work in. Interviewees point out that experience in the company is the way in which this is promoted, as this kind of knowledge is not documented anywhere.

> "We can have this very tight collaboration and then in this very tight collaboration, it's undoubtful who you want to speak with." (Software Developer)

> "You just have to have experience in the company and kind of understand. You have to know who to talk with, thankfully there's not many chains of telling one person to tell another person." (Software Developer)

One aspect which was consistent among those who were interviewed was the tools they used, which are consistent throughout the programmes. There is a view, however, that the tools are less important compared to the knowledge that is stored in these tools.

> "Tools are helpful, tools are definitely helpful, but the thing is the data in the tool is what matters. So for example I may have a million dollar tool, but at the end of the day inside that the documentation kind of sucks, and diagrams don't make sense, no one follows traditional aspects of creating diagrams, and they are created in a strange way, so these things are also very important." (Software Developer)

All of this information becomes helpful in better understanding both which are the channels through which teams share knowledge (the tools), as well as practical aspects about why communication happens in certain ways between teams (due to the divided-programme structure of the company). One of the main points emphasised by respondents was that despite there being different programmes, collaboration still happens between them, yet, at the same time, some collaboration (and by extension, knowledge sharing) is also limited by each programme.

4.1.4 Defining SECO

This theme aims at answering *RQ1.2 How do changes in the automotive domain influence how a company defines their software ecosystem?* As previously stated, in the 'Capturing Software Ecosystems' section, managers believe that a common understanding within the company leads to strong ecosystems, which is a way forward for the company to compete in the automotive industry, which has been impacted by digitalization and the need for connected services. To enable ecosystem capturing, the company needs to be able to define the ecosystem and the boundaries of this ecosystem. These boundaries are also influenced by changes within the automotive domain, which have been also been outlined in the section below.

Impact of the Automotive Transformation Process

In order to be able to successfully investigate ecosystem modelling, an important step was understanding more about the ecosystem in which the company operates. The automotive industry is undergoing a transformation process in the form of car sharing solutions and companies appearing in the market. As digitalization pushes OEMs to alter their value propositions and expand collaboration among other actors in the domain, transformation has been shifted towards focusing mainly on the customer (Grieger & Ludwig, 2019). Any such shift in focus requires an alignment with the other partners that are within the affected ecosystem (Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2019), for example in the types of systems that they have to develop. This push was also noticed by interview participants, with the biggest changes that they saw being the shift towards developing API-driven solutions and digital services instead of portals, further underlying the connected nature of the ecosystem.

Participants also confirmed that they are aware that this is the direction in which the industry is headed. They recognised the impact that this would have on the company, and the fact that software would take precedence over hardware when it comes to cars.

> "OEMs can still do their own things, but as long as if they see a bigger picture in collaboration,then why not? But it also depends on their business process and business analysis and everything. But I mean, overall if you want to change, if you want to grow, you have to collaborate, at least to some point." (Software Developer)

> "We try to have this common services that we want to use and then customize

> them. So, its different. Some cases its really 100% customized, but one of the major and biggest goals in 2020 is to accelerate the usage of WirelessCar products." (Product Manager)
>
> "I do believe digital services will make all the impact. Cause if they don't have the digital services sharing will really be impossible and until now digital services have been a sort of makeup." (Product Manager)
>
> "I would say we are not the whole way there yet, but I think we are more and more talking with, we want to build more isolated services that we can offer to a broader amount of vehicle groups." (Architect)

Management was particularly aware of the way in which these changes will affect them, and the role that digital services will play in this change. This has resulted in an awareness of the need to both offer more common services that can be reused among programmes, but also isolated services that do not depend on the rest of their components. Management has also marked a relevant goal that the company is pursuing in this domain, towards which they have already started exploring and expending their resources.

Focusing business decisions for the connected aftermarket

One of the main points mentioned during the interviews was the push for more partnerships and collaborations, which ties in with the company push towards common services and connected services. When asked about these partnerships, a number of examples were given (also see Subsection 4.1.1), ranging from technological partners, to research partners, and partners in co-creation.

> "we work together with partners within automotive safety and create a service like driver behaviour, so together with research from another company we look at how would be the safest way to drive and together so we provide this end to end service to the customer, but down beneath is co-creation with a partner." (Product Manager)
>
> "we need more people and partnerships." (Product Manager)

The interviewees were mostly focused on explaining the changes that they perceive, and the direction in which they see the company going because of these changes. Managers noted that one of the biggest push centres around the concepts of fleet and fleet management.

> "so when we discovered that, then suddenly the concept of fleet turns into now it's not a product, it's an approach to creating that multiple structuring and its based on a number of different solutions totally dependent on what the customer wants." (Product Manager)
>
> "So in the sense of what we have today, I would say we do have a number of different solutions for different customers depending on the needs, but in the sort of kernel its about making the car connectivity fleet-ready." (Product Manager)

The focus on partners and on co-creation between these partners highlights an awareness of the wider environment in which the company operates, even when the ecosystem is not mentioned explicitly.

4.2 Choosing modelling techniques for the study

Based on the results of the interviews which have been presented in Section 4.1, a decision was made to use the Software Supply Network (SSN) diagram and the Unified Modelling Language (UML) as the two modelling techniques which would be evaluated in the company. These choices were made for a number of reasons, which are presented in this section.

In Subsection 2.1.2, numerous modelling techniques were identified. When trying to select which modelling technique to use and attempt to improve, each of these was considered and assessed against the responses given by interviewees, together with discussions about ecosystem modelling, including with members of the case company. Although all the presented modelling techniques possess the ability to capture and represent software ecosystems, the reasons why they were unsuitable for the purpose of the study is explained below.

One of the most important aspects mentioned by product managers in the case company is the idea of partnerships, the layers in which they operate, and how the company takes part in the wider ecosystem together with the rest of their partners: "And of course, partnership based on a number of different layers, one is strategic suppliers, one is ecosystem, where we actually don't do business with each other, but we need to cooperate in order to launch services, and one is new business partners, meaning that together can actually provide services in co-creation and of course there are those gigantic tech cloud providers where we are in partnership with." (Product Manager). Based on this, it was assessed that the modelling language chosen needed to be able to present partnerships between different actors and how their services and position in the ecosystem aid in value co-creation.

Two modelling languages were considered suitable for modelling value. *e^{3}value models* enable the analysis and understanding in the creation and exchange of economic value (Arreola González, Pfaff, & Krcmar, 2019). Inter-organisational actors and their relationships within e^3 value models capture the economic value of activities within the ecosystem. In addition, e^{3}value models are by no means limited to expressing only economic value, with their use cases even extending as far as strategic value of APIs (Horkoff, Lindman, Hammouda, & Knauss, 2018).

The second value-focused modelling language was the *value network diagram*, which portrays the value exchange relationships between human actors within an ecosystem. This type of diagram aids in understanding and analysing how software ecosystem actors create value (Riasanow, Galic, & Böhm, 2017). Both modelling languages were rejected, as the case company was mostly interested in the collaboration between external actors (in particular companies and similar entities) of the ecosystem, in particular about partnerships and life-cycles that are part of the ecosystem, and not on economic value, or the exchanges between human actors.

The next modelling language considered was the *i* modelling framework*. This modelling language depicts strategic relationships among the actors inside the ecosystem where focal points rest on achieved goals and tasks (Yu & Deng, 2011). Although the case company was interested in understanding strategic relationships and prospective opportunities from these relationships, their focus was more on capturing the key players and their collaboration/relationship within the boundaries of the ecosystem as opposed to goals and rationales.

Finally, the last modelling language that was considered and rejected was the Business Model Canvas (BMC). While management was familiar with the BMC out of all of the modelling techniques that were proposed for ecosystem modelling in literature, this technique was too limited in scope and only identified key activities and resources for one collaborator or software company (Sadi & Yu, 2015), and therefore was not suitable for the company use case, which collaborates with a large number of external partners. Instead, a different modelling technique was necessary to attempt to model the company ecosystem.

4.2.1 Unified Modelling Language: Class Diagrams

Given that the case company is a software company, developers and architects comprise a large part of the organisation, with these individuals possessing extensive technical background and experience. UML is considered to be the standard for software development companies when it comes to modelling languages, although research indicates that this might not always be the case in practice (Petre, 2013).

This notion was reinforced while conducting interviews during the first iteration, as discussions surrounding the possible ecosystem modelling techniques showed that participants had knowledge of UML, although not as a method for modelling software ecosystems. And while UML was familiar to them, the usage of UML was not as ubiquitous as first expected, as one participant noted, "And there were many employees like me, new, who raised these questions during those onboarding sessions, that 'why are some diagrams a bit different than the others? Why can't we all use a standard UML or something like that? Why not?' But then the answer was not very obvious." (Developer).

UML is a complex modelling language that contains multiple modelling features (Gogolla & Richters, 1998). Out of all of the possible UML models, class diagrams presented the most comprehensive set of structures necessary to model ecosystems. The UML class diagram notation is used to create conceptual model structures of systems/applications, and more elaborate class diagram models can be translated into programming code (Berardi, Calvanese, & De Giacomo, 2005). The class diagram notation consists of an extensive array of constructs such as classes, attributes, operations, data types, multiplicity, and relationships, to name a few (Fakhroutdinov, n.d.). As stated by Berardi et al. (2005), the expressiveness of UML constructs can result in undetected consequences that may lead to misinterpretation and inconsistencies in the diagrams (Berardi et al., 2005). In order to focus on the ecosystem modelling aspects, the researchers chose to limit the components and constructs used to a subset of UML that can be represented at a higher-level of abstraction rather

than focusing on the technical details within the ecosystem. This subset provided all of the elements that would enable the models to present actors and the relationships between them in a way that would facilitate the capturing of ecosystems and the proliferation of a common understanding.

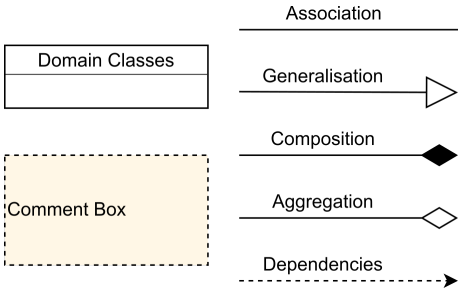

Figure 4.1: Unified Modelling Language (UML) Notation

The chosen components are presented in Figure 4.1, and an explanation of each component (Fakhroutdinov, n.d.) is also presented below:

Domain Classes describes real world objects and software objects.

Association defines relationships between classes.

Generalisation visualises the "more general than" relation.

Composition visualises the "has part" relation.

Aggregation visualises the "has removable part" relation.

Dependencies visualises that the information or behaviour of one class depends on another.

Comment box provides any information highlighting important points in the model.

4.2.2 Software Supply Network Diagrams

The second choice of modelling technique is the Software Supply Network Diagram (SSN). This was the second modelling technique that was considered because the results in Section 4.1 showed that respondents had different levels of awareness regarding stakeholders inside and outside of the organisation's boundaries.

Based on the interview conducted in Iteration 1, there are two main perceptions that the company has on software ecosystems: a technical representation and a partnership-focused representation (see Appendix A.4 for an example). As stated by Sadi and Yu (2015), "SSN does not support multiple views of a software ecosystem", this section of the model has to be supplemented. The Product Deployment Context model (PDC) provides an architectural overview of a running environment centred around a software product (Lucassen, Brinkkemper, Jansen, & Handoyo, 2012). The Software Supply Network (SSN) shows the relationships and cooperation of service organisations linked through software and hardware. As a result, components in the PDC model can be used in SSN in order to provide an architectural view of software ecosystems.

By supplementing SSN with components from the PDC model, the resulting model can be used by both managers and developers to promote a common understanding, yet it can also become more intricate when needed. This motivates the addition of the Product of Interest (POI) component to the PDC model, in order for developers to model the POI which is delivered by the Company of Interest (COI) (in this case, the case company is the COI and its services are the POI). Furthermore, the customer's customer component is relevant since in interviews, a product manager stated that co-creation exists and should be included in the software ecosystem even if the case company doesn't directly work with them.

The various components that SSN provides (see Figure 4.2) present a comprehensive list of elements to not only portray business relationships between various stakeholders (Boucharas et al., 2009), but also to enable the understanding of the intricacies of products, services, and components within the ecosystem. As stated by Boucharas et al., 2009, the SSN model shows inter-firm dependencies which enable business model reasoning, and is shown to have similar attributes such as that from UML modelling techniques, further solidifying this as an appropriate choice for the case company.

The elements that were used as part of SSN are listed below:

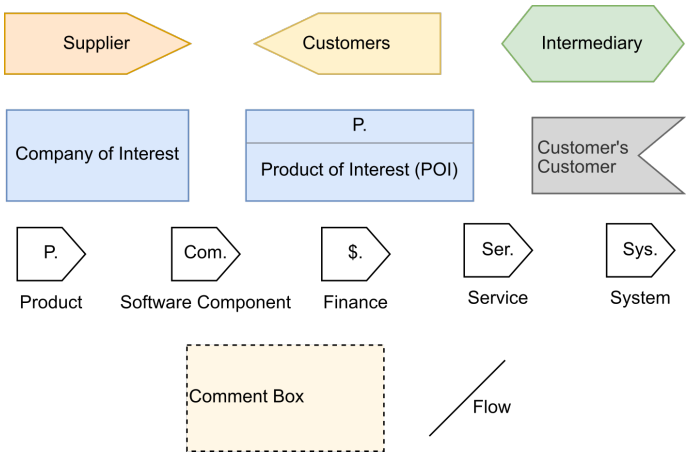

Figure 4.2: Software Supply Network Diagram (SSN) Notation

Supplier is an actor that supplies one or more required products or services.

Customer is an actor that directly or indirectly acquires or makes use of the POI.

Intermediary are actors such as Distributors, Re-sellers, etc, act as intermediaries between two parties.

Company of Interest (COI) delivers the POI in the business model.

Product of Interest (POI) is the main software POI in the business model.

Customer's Customer is when a Customer might have his own customers being provided with a product or service directly or indirectly from the COI.

Product (P.) is a required software product for the POI delivery to the customer.

Service (Ser.) is a means of delivering value.

Software Component (Com.) is part of a system or application.

Finance ($.) is associated with costs and payment.

System (Sys.) is intercommunicating components based on software forming part of a computer system.

Flow represents an artefact or service flow from one actor to another.

Comment box provides any information highlighting important points in the model.

4.3 Modelling Usability Study

As outlined in Sub-subsection 3.2.2.3, an online usability study was conducted with members of the company, with respondents being able to pick between the modelling technique presented in Section 4.2 that they could use to model their section of the company, and then answer a number of questions about their experience. The full answers to the open-ended questions are presented in Appendix B.3.1, and a selection of the models created by the participants is presented in Appendix B.3.2, with this section presenting an overview of these results. A total of six responses were received for this part of the study, comprising of one Architect, one Project Manager, and four Developers completing the exercise.

The answers for the questions in the survey were broken down into three main thematic data points: 1) Implementation of Modelling Techniques, 2) Representation of Modelling Techniques, and 3) Improvements of Modelling Techniques.

4.3.1 Implementation of Modelling Techniques

The respondents were asked "Why did you select the modelling technique that you chose to work with?" as an open question field in which they could write their assessment of the modelling technique that they chose. A total of four respondents completed the exercise using SSN and mentioned that they liked the amount of details in the model and highlighted that the model would be useful for presenting information to stakeholders, but also emphasising how stakeholders are involved in the ecosystem as presented in Figure 4.3.

One respondent claimed that SSN seemed the appropriate choice given that the main focus pertained to modelling the external stakeholders involved within their programme and the relationships that flow between actors (modelling the software ecosystem surrounding the programme that the individual is working in, namely the exchange of data, information, resources, and artefacts). The same respondent claimed that UML is better suited for technical details, and although it is possible to apply UML for the given task, it does not lead to a better comprehension of the actors within an ecosystem. Another respondent said "it was easier to focus on external stakeholders and their involvement using this approach."

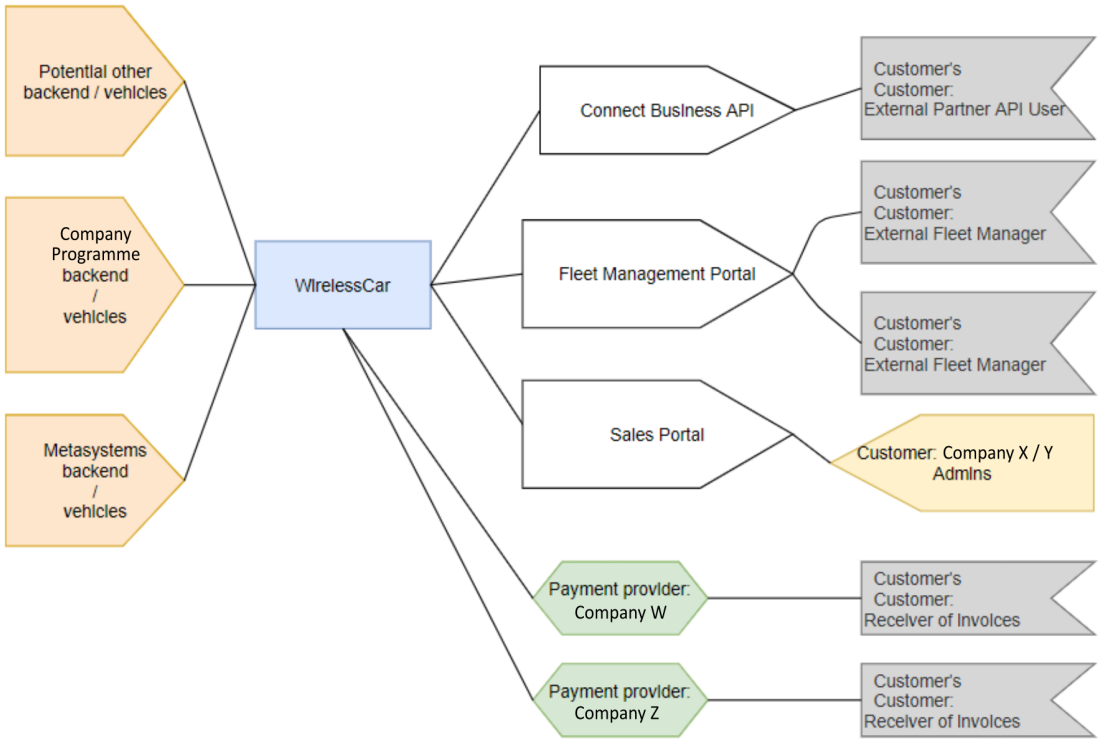

Figure 4.3: SSN model created by a study participant

In addition, another respondent mentioned that "there is an inherent mental association between using UML and depicting a software down to its smallest, representable details.", highlighting the granularity which they considered to be the main benefit of UML. As an example, Figure 4.4 shows one of the UML models that one of the participants created during the usability study, emphasising the more technical orientation of the model.

4.3.2 Representation of Modelling Techniques

To assess their experience using the modelling technique, the respondents were asked four questions on a five-point Likert scale.

The first question asked "Does this modelling technique provide a good visual representation of the ecosystem?", with responses raging from strongly disagree to strongly agree (see Figure 4.5). Three individuals agreed that the SSN modelling technique provided good visual representation of the ecosystem surrounding the programme they are working in, and this perception was the same among two individuals who chose UML as a modelling technique.

When asked "What did you think of the modelling technique?" on a scale from difficult to use to very easy to use, the observations made by four individuals using the SSN modelling technique showed that the majority of responses found the level of difficulty to be medium. In contrast, the participants who chose UML thought that the technique was easy to use (see Figure 4.6).

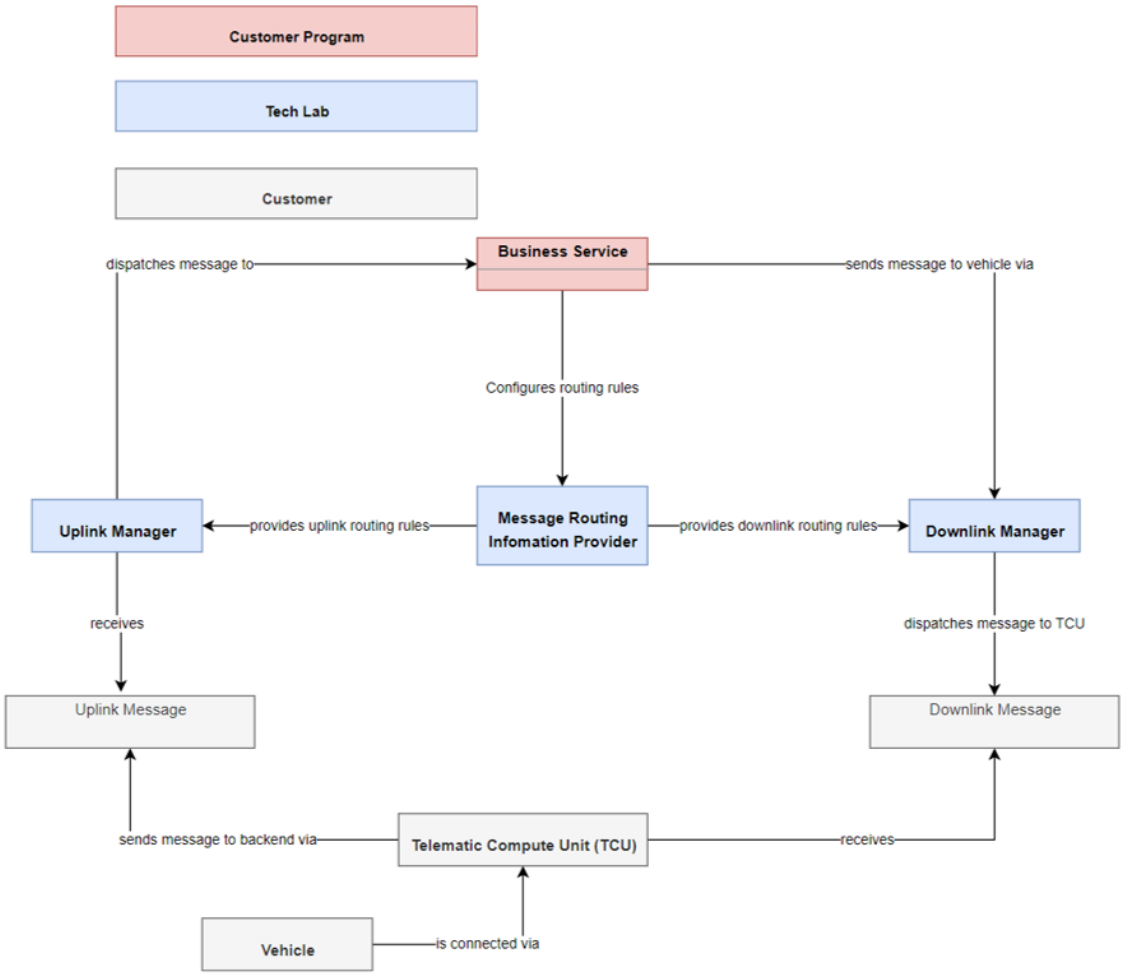

Figure 4.4: UML model created by a study participant

Respondents were then given the question, "If your model were to be presented to others within [your programme], do you agree that they will understand this ecosystem?". The scale ranged from strongly disagree to strongly agree, and although the test subjects were impartial to their opinions on both the SSN and UML modelling technique, all individuals agreed that their ecosystem models would be understood by those working within their respective part of the company (see Figure 4.7).

The respondents were then asked "Do you think that ecosystem models could be relevant for future use cases in the company?" on a scale from strongly disagree to strongly agree. The responses showed a positive opinion on using ecosystem models in the future, with all individuals who used SSN agreeing that the modelling technique would be applicable. Only one respondent was ambivalent about the use of ecosystem models (see Figure 4.8).

4.3.3 Improvements of Modelling Techniques

One of the main problems individuals faced when creating their ecosystem model was that the modelling techniques had very similar elements. As one respondent

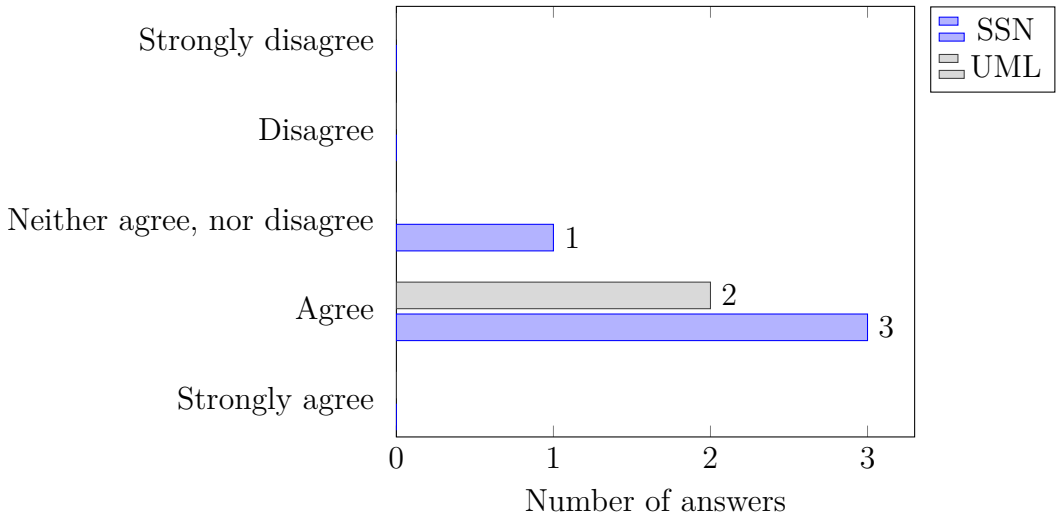

Figure 4.5: I2Q3: Does this modelling technique provide a good representation of the ecosystem?

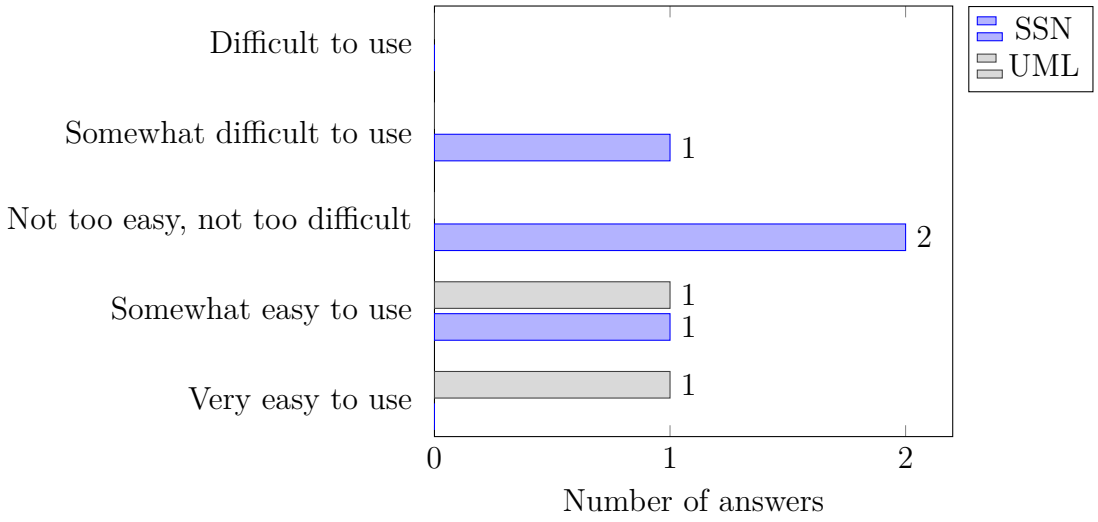

Figure 4.6: I2Q4: What did you think of the modelling technique?

mentioned, "the fact that many elements were identical or at least similar (the white boxes formed like arrows, representing different things such as 'software' and 'service') confused me". Two respondents stated that the "exchange of money could be excluded from the model, it is difficult to accurately represent without putting a wall of text besides." One respondent said that the modelling technique could function without differentiating between the Component, System, and Service flow elements representing artefacts or service "since it makes little difference to external stakeholders."

When asked whether additional components should be added to enhance the model and the representation of the ecosystem, one respondent stated that the flow lines may cause confusion and that "defaulting to directional arrows (allowing bidirectional in some cases) would perhaps be a good idea to enforce an understandable

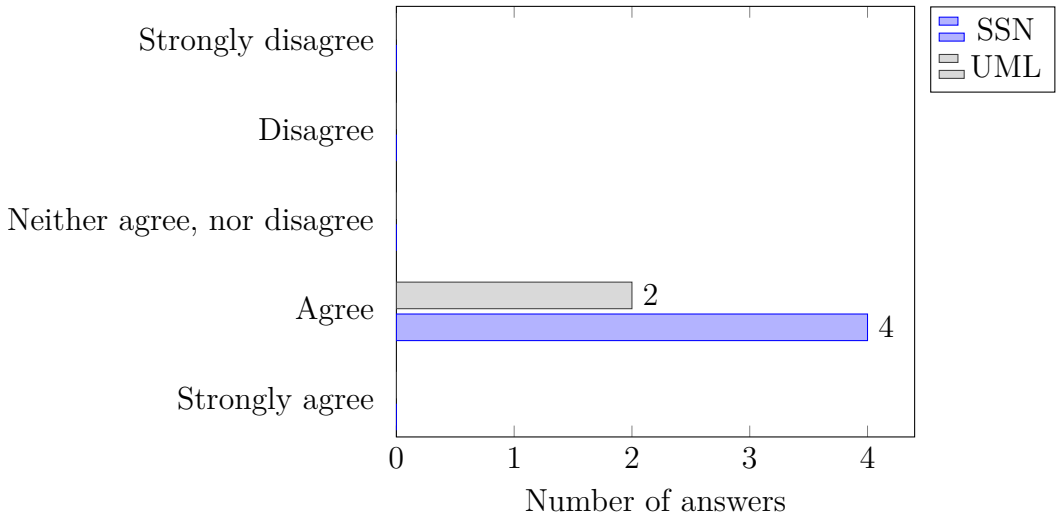

Figure 4.7: I2Q5: If your model were to be presented to others within [your programme], do you agree that they will understand this ecosystem?

structure."

One respondent stated that clarification from the component description in the workshop "gives the opportunity to clarify if something needs to" and one respondent mentioned that no components need to be further added to enhance the model, as "less is more in this case."

Shifting to the UML modelling technique, both respondents believed that the elements in the model helped to represent the ecosystem. Nevertheless, both respondents also mentioned that the UML modelling techniques could be more detailed in order to present all flows and possibilities in the ecosystem, which is also dependent on the focus/concern of the ecosystem being modelled.

4.4 Modelling Technique Improvement Proposal

The results in this section are used to answer *RQ3. In what way can an existing modelling technique be improved or adapted following company use cases?* To be able to evaluate possible improvements, the results of the usability study have been summarised in Table 4.2, with the key characteristics of each modelling technique being highlighted; these characteristics are the ones that have been considered when coming up with a list of possible changes to one of the analysed modelling techniques.

The findings of the online usability study indicate that, while more respondents favour SSN over UML, respondents had different perceptions on the use case for each technique. According to the respondents, the UML modelling technique provides a more comprehensive view of software ecosystems (when considering the types of components that are available as part of the model), while SSN provides a better way of representing stakeholders within the ecosystem. Despite this discrepancy, the models created by the subjects on both techniques are believed to be comprehensible if the models were shared within their respective part of their company.

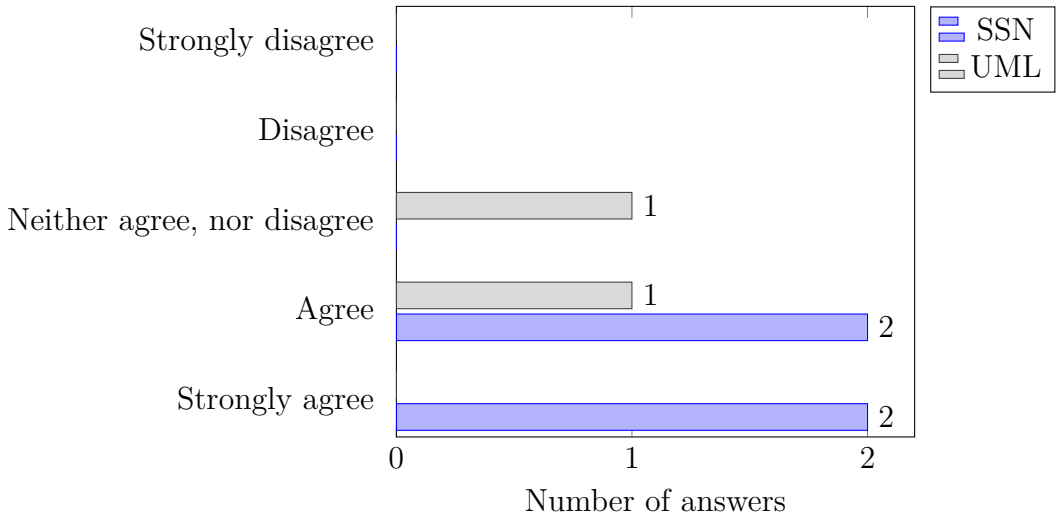

Figure 4.8: I2Q8: Do you think that ecosystem models could be relevant for future use cases in the company?

Given that the SSN modelling technique was the one used more among the respondents (at a 2:1 ratio), SSN was chosen as the technique that would be improved. Therefore, all of the proposed changes to the model were based on SSN. This decision was reinforced by the fact that all respondents who chose SSN believe that the SSN modelling technique could be relevant for future use cases in the company. As a result, three concrete improvement suggestions were created based on the feedback given by the respondents regarding modelling techniques.

The three changes proposed are independent from one another and can function alone as part of the SSN model, without depending on the preceding change to be used as well. This allowed for an independent evaluation of each, in order to understand which changes were seen as more valuable to modelling in the company, as well as to expedite breaking down and analysing the data on each change.

Table 4.2: Summary of usability study results

SSN	UML
4 respondents	2 respondents
Implementation of the modelling technique	
The model would be useful when presenting information to stakeholders due to the amount of details in the model.	UML is better suited for more technical details.
Shows stakeholder involvement in the ecosystem.	Actors within the system are less comprehensible in UML.
Representation of the modelling technique	
Provides good visual representation of the ecosystem (75% responded).	Provides good visual representation of the ecosystem (50% responded).
Individuals believe that the technique is neither easy, nor difficult to use.	Individuals believe that the technique is easy to use.
All respondents claim that the modelling technique could be relevant for future use cases in the company.	One respondent claims that the modelling technique could be relevant for future use cases in the company, while the other respondent is ambivalent.
All Individuals believe that their ecosystem model will be understood within their respective part of the company.	
Improvements of the modelling technique	
The trade relationships (Software Component, Finance, and System) could be removed from the modelling notation as it presented confusion.	The modelling technique could be more detailed to present all flows and possibilities within the ecosystem.
No other component needs to be added; less is more.	
Directional and bi-directional arrows could be added to enforce a more comprehensive structure.	

4.4.1 Bi-directional arrows

The first change combined two related observations that the respondents pointed out as part of the study. Firstly, one comment indicated that the flow between actors was not clear, with the change to the technique introducing bi-directional flow arrows that can provide a clear view of the direction in which the information is distributed. Secondly, results indicated that some components in SSN are not useful, in particular that the amount of trade relationship offered by the model was confusing. To solve this, most of the trade relationship markers were removed altogether (except Product and Service), as they did not provide sufficient value to represent software ecosystems in the context of the company. See Figure 4.9 for a graphical representation of proposed changes.

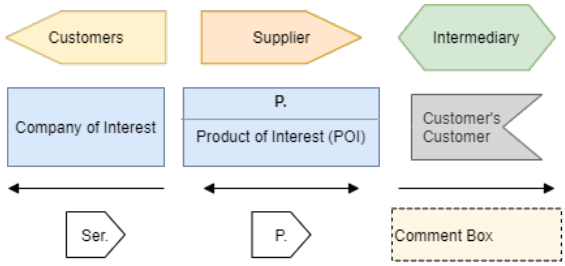

Figure 4.9: Change 1 (Bi-directional arrows)

4.4.2 Dependency arrows and component redesign

Participants in the usability study indicated a greater familiarity and ease-of-use for UML, which was one of the reasons for which this technique was chosen to be evaluated in the first place. In contrast, participants were less familiar with SSN, which added an additional learning curve. This was not considered significant enough to prevent it from being usable, or unfit for being improved. To promote additional familiarity with the modelling techniques, the second change focused on introducing elements inspired from UML.

The first part of the change involved a more streamlined visual representation of the components, in which all shapes became rectangular boxes, while preserving the colours previously defined by SSN. The second part of the change inspired by UML was the addition of dependency arrows, to enable a more granular representation of the relationships between the actors. The preservation of the Product and Service trade relationship allows it to become an (optional) extension of the dependency flow, showing the vehicle through which the dependency is expressed. Figure 4.10 presents the new visual look of the components.

4.4.3 Icons

The third proposed change once again had to do with the visual representation of the SSN model. Given that some of the respondents found parts of the model to be confusing, this change was meant to address these concerns. Icons add visual clarity

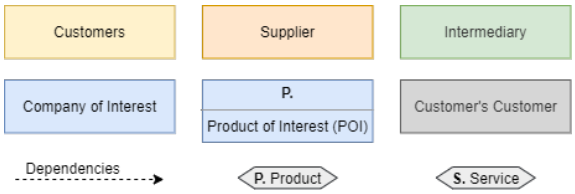

Figure 4.10: Change 2 (UML-inspired dependency arrows)

to models that allows users to interact with the given components and help people quickly find information in the model (Harrison, Hsieh, Willis, Forlizzi, & Hudson, 2011). Icons also provide a more clear differentiation between actors than colours (e.g. for colourblind people; in situations in which the models have to be displayed in greyscale). Figure 4.11 shows the new components with their associated icons.

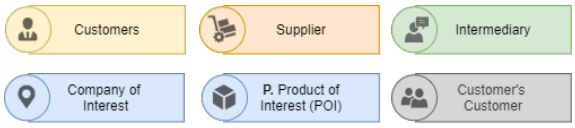

Figure 4.11: Change 3 (Icons)

4.5 Results from Redesigning Modelling Techniques

As outlined in Sub-subsection 3.2.3.2, the resulting changes were evaluated using a survey. The survey comprised 10 questions, which were divided into 5 sections. Respondents had the task of assessing the three proposed changes for model redesign and analysing which choice they favoured. They were also given the option to suggest additional improvements. The survey concluded with respondents being tasked to select which prospective use cases they could envision for these redesigned models. A total of 7 responses were collected during the survey; this section presents a summary of these results.

4.5.1 Model Redesign Assessment

This theme analyses each of the changes as an independent potential improvement to the modelling technique.

4.5.1.1 Redesign 1: Bi-directional arrows

When presented with the choice of replacing the trade flow components with arrows which can also express the direction of the flow between components, respondents considered this change mostly positive, but at the same time the responses covered a vast array of opinions (see Figure 4.12). Analysing their individual explanations reveals that the flow direction was the biggest reason why this change was considered useful, although one respondent also claimed that this feature was already present in the models.

> "the change is useful because it will be clearer to follow the flow between entities." (Respondent 3)
>
> "Easier to understand flow that way then in original" (Respondent 6)
>
> "Having arrows make it easier to see the direction of the so called 'flow'. It clears up in understanding the collaboration." (Respondent 7)

In addition, individuals believe that by removing the other components and having only the Product and Service component, the modelling technique would be further understood by individuals in the company.

> "I think that the flow alternative is covering the most needed relationships and value streams. But the removal of Com, $ and system is generally good since they only confuse the picture." (Respondent 2)
>
> "it will be a useful change, makes use of simpler elements (Service, Product only) which are understood by people in all roles." (Respondent 4)

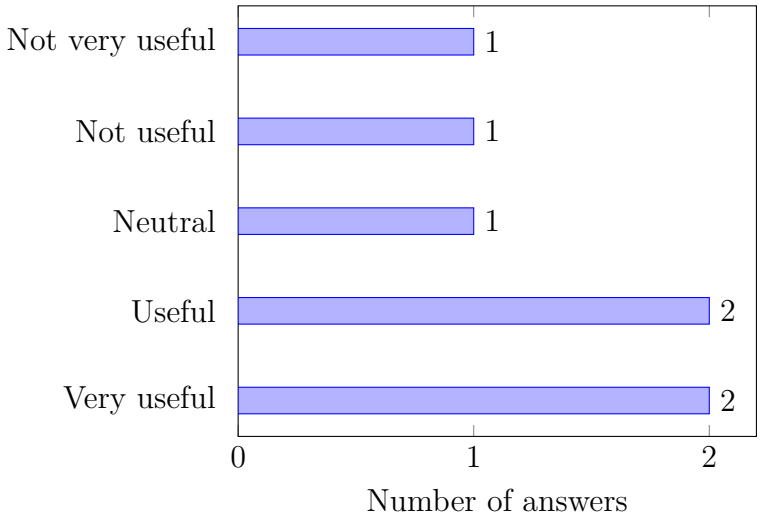

Figure 4.12: I3Q1: How would you assess this change to the model (bi-directional arrows)?

4.5.1.2 Redesign 2: Dependency arrows and component redesign

When presented with the choice of adding arrows showing component dependency and redesigning the visual look of the components, respondents were once again spread out on the entire range of possible responses. Figure 4.13 shows that the answers lean more towards positive-to-neutral opinions about this proposed change.

According to the free-text answers, two respondents have similar views on the added dependency arrows in the model with some liking the added component and another rationalising that it may not be very useful.

> "to show dependencies is a good add-on, as well as streamlining the components to avoid unwanted directional misconceptions." (Respondent 2)

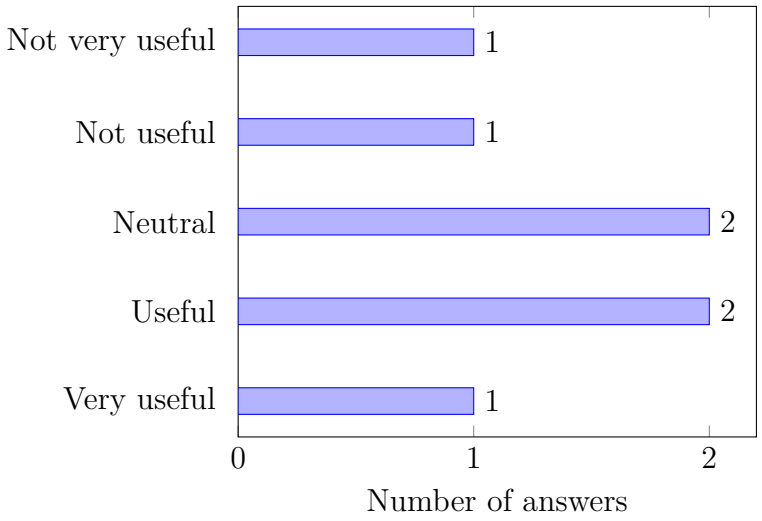

Figure 4.13: I3Q3: How would you assess this change to the model (dependency arrows + component redesign)?

> "Seems like a good idea to differentiate between dependencies and flows." (Respondent 3)
>
> "Dependencies may help to an extent. The previous arrows were more helpful as you can establish relationships such as dependencies as well if you can model that using other components. Dependencies would be good though as you can see what or who is dependent on others." (Respondent 7)
>
> "Dependencies are important overall to highlight to make sure that high level picture is understandable and easier to implement, as it would be visible on what to start at." (Respondent 6)
>
> "The change with the dependency arrows is not quite so useful in my opinion." (Respondent 4)

In terms of streamlining the components to keep them uniform and simple, two respondents believe that streamlining the components is a useful redesign in order to convey clarity to the model. One respondent mentioned that streamlining the components can be difficult to people who have a condition to colour blindness.

> "The redesign of the components may be an issue for people with "color blindness" though since it relies only on different colors to describe the intent, you need to be clear with the text in that case." (Respondent 3)
>
> "Streamlining component representations is quite useful, avoids needless confusion about placing things a certain way." (Respondent 4)

4.5.1.3 Redesign 3: Icons

The final question for individual changes asked participants to assess the usefulness of adding icons to the component boxes. This time, Figure 4.14 shows that most respondents were neutral on the change (three respondents), while one thought it was not useful and the other three considered this change to be useful or very useful.

The icons are only useful if they are depicted appropriately for the given component in order to facilitate in understanding what the component represents.

> "Icons are generally good, but it is very important that the icon is easy to understand, might for example change the Company of interest icon since that is a location pointer :) But generally icons make the picture 'more interesting' and easier to remember." (Respondent 2)

> "Easier, more recognisable, very useful. Would be fine without if every element was a different colour but since that is not the case, icons would be quite useful." (Respondent 4)

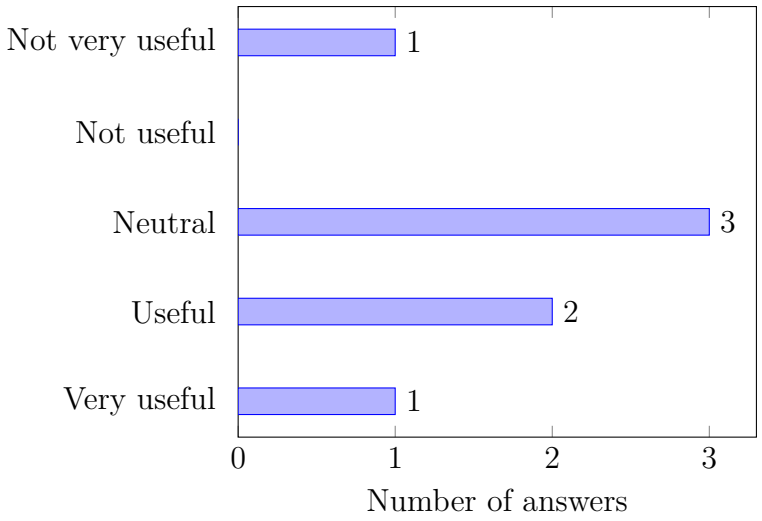

Figure 4.14: I3Q5: How would you assess this change to the model (icons)?

The comments which did not consider the change useful believed that the items either added too much visual complexity to the diagrams, or that they did not provide any additional information that could not be assessed from the original model notation.

> "I don't think the icons would help so much as the other changes. It could also be confusing for some since it will add too much to the diagram. There are already so many components." (Respondent 7)

> "I think icons do as good job as geometrical shapes." (Respondent 5)

> "Answering this from value perspective - not sure if provides value to be honest, it's nice to have, looks more modern look, but in the end I don't feel that it provides extra explanation (again, imho)." (Respondent 6)

4.5.2 Composition Assessment of Model Redesign

This theme looks at all of the proposed redesign changes and tries to analyse, compare them to one another, and assess which of them is more useful or less useful according to the responses given by the participants in the survey.

Respondents were asked to select which changes they found would make the model better in their opinion. Multiple changes could be selected, or none. Only one respondent chose to not select any of the presented changes (believing that they would not be an improvement for the presented modelling technique), with every other participant selecting one, two, or all three possible changes. Figure 4.15 presents the resulting tally of selections, showing that out of the presented options, five out of seven people assessed that icons would be the most beneficial change to the modelling technique, followed by dependency arrows, and finally, less than half of the participants thought that bi-directional arrows would improve the model.

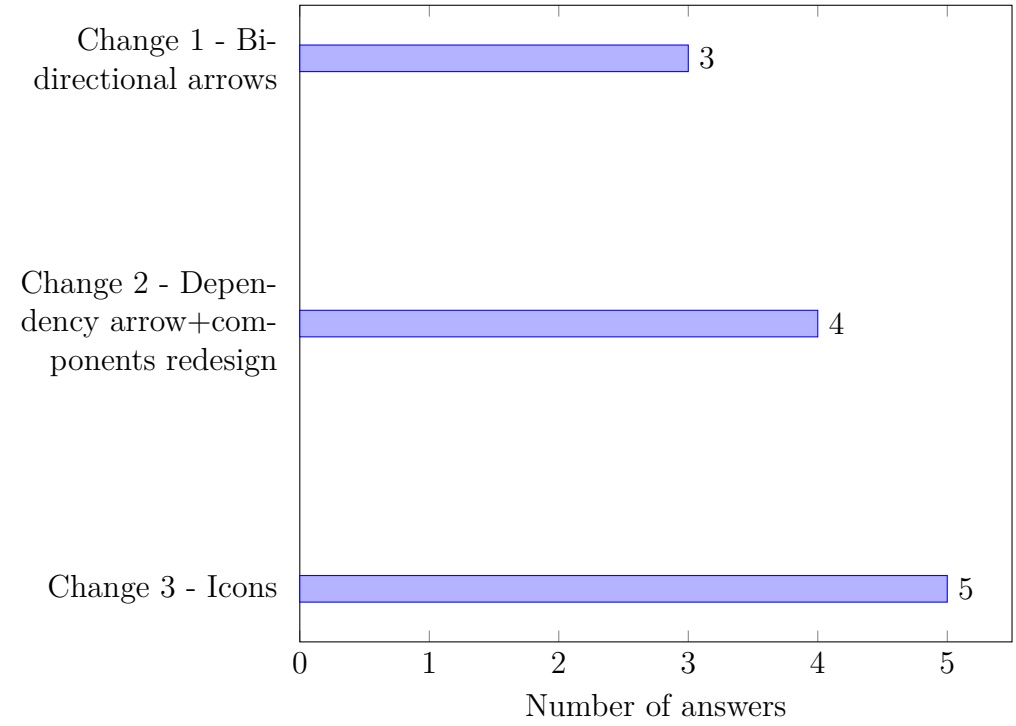

Figure 4.15: I3Q7: Which of the presented changes would make the model better? (select all that apply)

To further streamline the answers of the previous question, respondents were also asked to pick just one change that would bring the most value to ecosystem models, with the option that none of the changes would bring value. The results in Figure 4.16 indicate a different way to prioritise the changes, with bi-directional arrows coming on top as the change that brings the most value to ecosystems, and two participants thinking that none of the changes would be useful for this use case.

When asked what other improvements they would envision for the modelling technique, respondents indicated either that the presented improvements would be good (with no new suggestions), or even that no new improvements are necessary in general. However, a few mentioned a few additional ideas that they had for model improvements:

> "Possibility to show sequential relationships between different entities. " (Respondent 2)

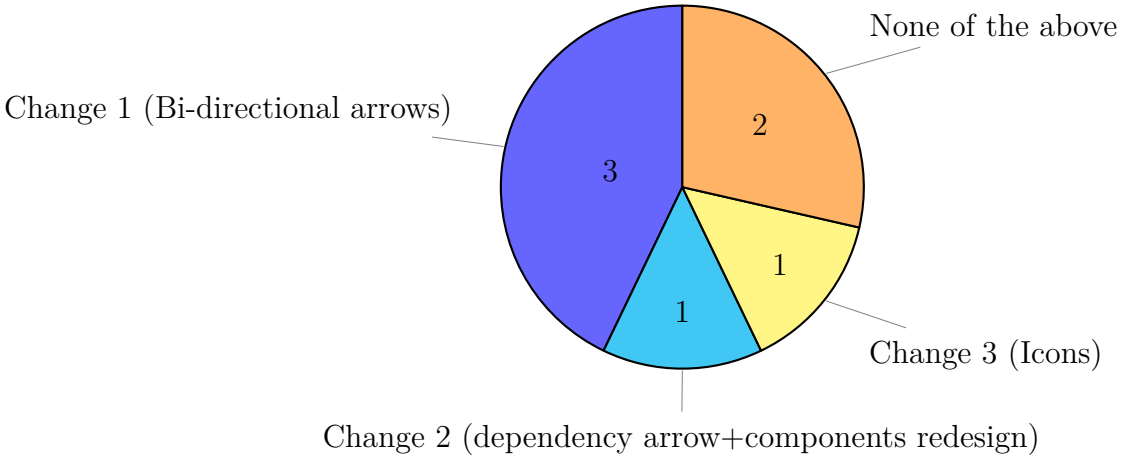

Figure 4.16: I3Q9: Which of the three changes would bring the most value to ecosystem models?

> "Grouping consumers - producers maybe" (Respondent 6)
>
> "Also, an additional generic box for 'Change 3' would probably be helpful." (Respondent 3)

One respondent noted that there is no need for using a new tool in the company, with the more important factor being the ability to comprehend models across different people in the organisation: "I would say that the original models are fine and probably don't need any changes, the challenge is having the competence to understand them across the company. As it is right now I don't see any need to use a new modeling tool." (Respondent 1)

4.5.3 Prospective Applications of the Redesigned Model

The last question of the survey asked participants to pick from a list of possible use cases which they think would be most likely to be useful for the case company in the future. The respondents had a total of 10 different choices (derived from the information on ecosystems that was collected from the interview answers), from which they could pick as many options as they wanted or none, and Figure 4.17 shows how these choices were distributed among use cases. As seen in the aforementioned figure, the most common use case that the participants perceived for the modelling technique was related to documentation (five respondents), with the next most common use cases being related to knowledge sharing, business strategy development, and visualising ecosystem changes.

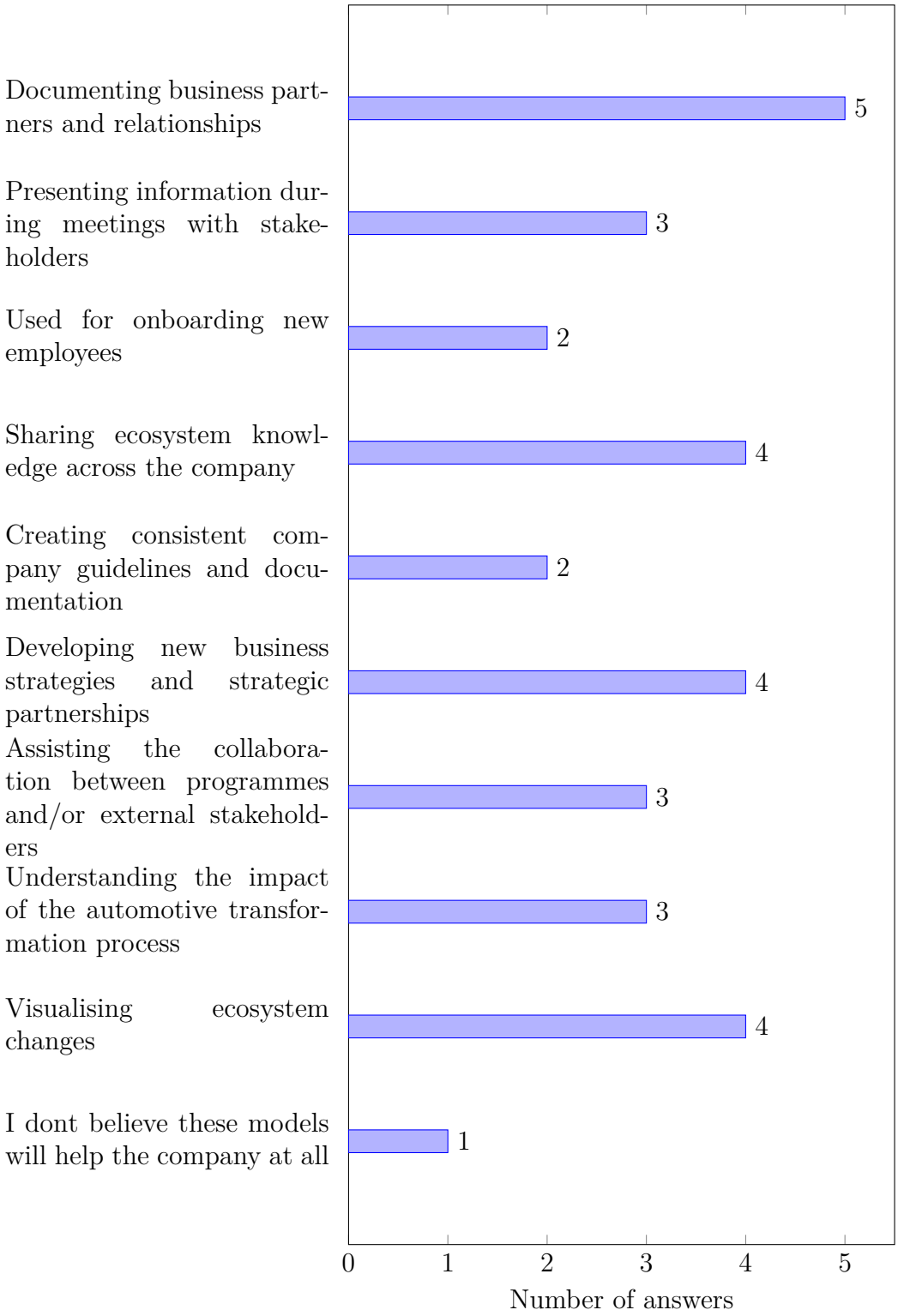

Figure 4.17: I3Q10: In what ways could you see ecosystem models (in particular this modelling technique and changes) be used in the company? (pick all that apply)

5

Discussion

5.1 Different Perceptions of Software Ecosystems

This section discusses *RQ1.1 What perceptions do key players in the organisation have in understanding the role of software ecosystems?*.

Based on the results presented in Subsection 4.1.1, different perceptions can be observed at different levels of the organisation. A first observation is that the definition of ecosystem varies significantly between individuals and their roles within the organisation. Managers view an ecosystem as a collaboration between actors, although they do not necessarily recognise the software aspect as being the main connection point between actors. Furthermore, managers are more familiar with the term "ecosystems" at the organisational and business level, whereas architects and developers mostly understood ecosystems as technology focused, such as frameworks, interfaces, and technical architecture.

As far as ecosystem partners are concerned, the managers and developers had diverging opinions as well. The OEMs were recognised as the main stakeholder for each programme by every interviewed participant. With each programme organised as an independent entity, with its own process and structure, interactions between different programmes are viewed as interactions with an external stakeholder. This view is expressed by developers and architects, whereas managers, who have a wider view of the partnerships and interactions, do not perceive the presence of an internal ecosystem inside the company. According to managers, ecosystem partners are those partners which operate outside of the company boundaries and are not limited to direct business partners, but also service facilitators.

An interpretation of this problem is that developers operate within their respective teams, as part of independent programmes at the case company, where they lack much of the bigger-picture view which would be necessary for them to have the same perception as the managers. This limited view aligns with the social cognitive research of "frames" presented by Orlikowski and Gash (1994), with these encompassing both existing knowledge, as well as assumptions about a specific topic. The concept of frames denotes that organisational reality may differ among individuals within the company in their actions and understanding (Orlikowski & Gash, 1994). These actions and understanding include knowledge, assumptions and expectations that are conveyed through verbal communication, images, languages, and even stories. The structure of frames is flexible and may shift the content of context due to

changing variables, resulting in structured webs as opposed to having linear meanings (Orlikowski & Gash, 1994).

Frames are a tool that help in shaping an individuals' interpretation of phenomena that take place at an organisational level. They help in guiding these individuals' actions within the organisation in a way that is aligned with their perceptions and assumptions (Orlikowski & Gash, 1994). However, van der Linden and Hoppenbrouwers (2012) point out that even when individuals share the same conventions, the resulting interpretations can still be different among practitioners; this is consistent with the answers provided by both developers, architects, and managers in regards to their perceptions of software ecosystems.

These findings answer RQ1.1 by showing how different perceptions are based on the individuals that work in the case company. There is no coherent perception of an ecosystem across the hierarchical levels of the company. Developers and architects are more aware of the technical ecosystems in which they operate, while managers recognise ecosystems closer to the definition presented by Jansen and Cusumano (2013).

The implication of this finding is that, due to practitioners having different perceptions on software ecosystems (both in how they are defined, and where to draw the boundaries of the ecosystem), there is no common language to discuss the role that the ecosystems play in the company. According to Sadi and Yu (2015), the understanding of software ecosystems can be propagated through the creation of ecosystem models, and this can become the outlet to assist practitioners (developers and managers in particular) in finding a common vocabulary to align their perceptions with one another.

The additional implication of this finding would be that the best way to approach this divide is to have two different modelling languages to present software ecosystems: one that is more familiar to management and their own view of the ecosystem, and another for the more technical-focused members of the company, focused on the internal representation of the ecosystem. This does not match the stated goal of having a consistent view of the ecosystem that has been presented by members of the case company, one that would promote a common understanding between different levels of the organisation and which would facilitate knowledge sharing between teams and individuals.

5.2 How software ecosystems are captured

This section answers *RQ1 How are software ecosystems currently captured, documented, and shared in a software company within the automotive domain?*. Based on the results outlined in Subsection 4.1.2 and Subsection 4.1.3, it can be observed that a few key points arise. Knowledge sharing and communication are encouraged and promoted via the agile methodology used throughout the company. These forms of communication include stand-up meetings, architecture meetings, case company lunch-talks, to even informal discussions – in summary, mostly verbal communication. Another key point stresses the importance of collaboration and documentation

within teams and across programmes. While this might contradict the agile methodology that the company is employing, interviews suggest that such amount of documentation is helping members of the company more than impeding them. Different perceptions on what a software ecosystem is influences the way in which participants answer when asked about documentation practices. The more technically-focused positions exemplify technical diagrams and no knowledge of ecosystem diagrams, while management talks about the existence of both technical and ecosystem models. When asked to view this latter model, the presented image showed a very high-level overview of the different categories of partners that are in collaboration with the company, as well as examples in each category. This diagram did not present any additional detail about the relationship between these different actors, and did not follow a standardised way of presenting this information (see Appendix A.4).

To help in discussing ecosystem capturing, a few modelling techniques were shown to participants when they asked for them. Management showed familiarity with the Business Canvas Model, whereas developers were more familiar with UML, matching the perceptions that they have of ecosystems in general. This reinforced the discussion presented in Section 5.1 where organisational reality is based on different individual roles within the company.

One interviewee also mentioned that when it comes to organisational partners, there is one key member of the organisation who is in charge of keeping track of these partners and their collaboration with one another and with the company.

> "So [the partnership manager] is actually the one having the whole list of partners within the different areas. And [the partnership manager] is also helping the sourcing with really bringing up all new suppliers and then sourcing is focused on which partners to buy consultant services or tools and so on. But [the partnership manager], is really the one in collaboration with product managers, really keeping everything together, which are tools partners, who are technology partners who we actually create stuff with, who are just simple suppliers, we don't create anything but they are strategic enough... [the partnership manager] is the only one who is all over the place." (Project Manager)

It is understood that this position is the main way in which the company captures their ecosystem partners, which poses a number of practical problems in sharing the resulting knowledge. While this position works in the operations of the company (there was no indication that they were unhappy with the way the partnership manager functioned), the diverging perceptions of the different members of the organisation show that this approach does not assist in the common understanding of ecosystems, which is one of the main points that management wishes for the company (as presented in the quote below).

> "That is actually the most important thing with [case company], to build this common understanding and knowledge and competence on how do we build connected services in the best way, and we use that in all programmes, and at the same time manage to do the customisation. That creates really strong

ecosystem or solution. We hope so." (Project Manager)

Research Question 1 asks, *How are software ecosystems currently captured, documented, and shared in a software company within the automotive domain?* The lack of a consistent vision among members of the organisation make it difficult to answer this research question, because there are multiple interpretations of which ecosystem needs to be captured. At best, it can be answered by saying that, as far as the management's view of ecosystems is concerned, the partnership manager is the way in which the company has chosen to capture their ecosystem. This single individual retains all the knowledge about partners and partnerships, which presents its own issues if this individual becomes indisposed for any reason (sickness, injury, layoffs, etc.).

However, since the company wishes to enhance the understanding among individuals, it shows that new methods might be needed to accurately capture ecosystems. One way that this goal can be promoted in the company is through the introduction of formalised ecosystem modelling, as literature shows that modelling languages can facilitate this (Jansen et al., 2019).

5.3 The impact of digitalization on defining software ecosystems

This section answers *RQ1.2 How do changes in the automotive domain influence how a company defines their software ecosystem?*. To best answer this question, the first step needed was to examine the disruptions within the automotive industry, as they are parallel to the business operations, software development and requirements of the case company. Subsequently, it was necessary to compare the outcomes of these disruptions to the evolving ecosystems within the case company.

Disruptions in one part of the ecosystem ripple across all other actors in the ecosystem (Kohtamäki et al., 2019; Lichtenstein et al., 2018). Digitilisation and the adoption of new technologies lead organisations to collaborate in order to ensure their own success and compete in the automotive domain (Sadi & Yu, 2015). Automotive business models are changing due to shifting customer expectations and the increasing advancements of digital services, pushing OEMs towards software services (Grieger & Ludwig, 2019). These factors enable mobility through the concepts of platform services, shared vehicle usage, and connected services. Furthermore, customers have become "not just the consumer of goods" (Grieger and Ludwig, 2019), but have become the centre to which developed services are attributed.

At the developer level, this was noted as a shift towards APIs, whereas at the management level this was noted as an increased demand for fleet services, which the company is attempting to solve alongside their respective customers - the OEMs. This is just one example of how changes affect each member of the ecosystem, with the case company reacting to the same disruption, because its customer, the OEM, has reacted to the shift in customer-focused solutions.

While the interview subjects do not directly identify the source of this disruption

or that it is an impact of the ecosystem in which the company operates, there is an implicit awareness about this when it comes to those in management. One of the main points being made is the need for new partnerships and partners with which the company can collaborate. The types of partnerships that are being sought provide an initial overview of what type of requirements the company has in defining the ecosystem in which it operates.

One noteworthy point is that there are no limits to the types of partners that are present in the ecosystem, as long as these partners enable either co-creation, or mutual, but indirect cooperation. A telecom company which enables the company services to function in its area of operation becomes a partner under this framework. This is a very broad approach to recognising ecosystem partners.

However, the results show a number of ways in which the disruptions in the automotive industry influence the company ecosystems, and how the ecosystems are perceived and captured. Due to the lack of a consistent view of this ecosystem (or ecosystems) inside the company, a number of deductions on ecosystems may be able to answer this question. Between the two different perceptions of the ecosystems that were discovered, the disruptions in the automotive domain are more relevant to the management view, where stakeholders represent outside entities to the company.

In practical terms, the company's ecosystems are primarily affected by the OEMs that the company is directly partnered with (their customers), and OEMs are directly affected by disruptions in the automotive domain. To be able to achieve the company vision of becoming a leader in digital services within the automotive domain, the company cannot ignore these disruptions either. They have to anticipate the kind of changes that are expected, and be prepared to align themselves with their customers.

As the previous sections outline, one way to become aware of these changes and to share the vision between members of the organisation is through modelling the resulting ecosystem. This means that any ecosystem that the company would want to model would have to not only take these disruptions into consideration, but also focus on the areas which the company is most invested in as well, because this model can become a valuable tool in discovering new opportunities and partnerships in the ecosystem. The relevant changes in the industry must have a way to be represented in the chosen modelling technique, and understanding which disruptions are the most relevant is only the first step towards selecting a modelling technique that could express these changes. A second step is understanding the boundaries of the ecosystem, which would also be enabled through keeping track of the changes in the automotive domain, and presenting these changes to key players of the organisation in a way that promotes mutual understanding.

The answer to RQ1.2 is that the prerequisites for defining software ecosystems are complex, and consist of multiple variables that are subjective, and which would be difficult to outline in a single study. However, these prerequisites are not static, and the digital transformation of the field has a direct impact on what types of actors are going to be present in the ecosystem. Modelling becomes a way to help the company keep track of these changes and disruptions.

5.4 Modelling techniques as a tool for capturing software ecosystems and for collaboration

This section answers *RQ2 Which existing modelling techniques provide support in capturing software ecosystems at different levels of an organisation within the automotive domain?* According to the results presented in Section 4.1 and the discussion presented in Section 5.1, it is evident that different perceptions of ecosystems exist within the organisation. Developers and architects perceive ecosystems to be low-level and technically-oriented, while managers perceive ecosystems at a higher level of abstraction, focused more on the external stakeholders with which the company collaborates.

The boundaries of the ecosystem are therefore also defined in different ways, with the more technically-oriented vision having smaller boundaries compared to the wider, more wide-encompassing ecosystem that is perceived by management. The models created by the respondents provide a way to evaluate the actors and relationships used by the study participants, and how the modelling techniques facilitate in defining software ecosystems, their boundaries, and how key players co-exist within the ecosystem. While two ecosystem modelling approaches would seem like an easy solution to this difference, the company wishes to be able to promote a common understanding on all levels of the organisation, and with the prevailing focus on verbal communication among members of the organisation, a single modelling technique should be able to bridge this gap.

Through RQ2, the goal was to see which modelling techniques can be employed at different levels of the organisation. For this, two modelling techniques (SSN and UML) were assessed (see Section 4.2 for the rationale behind the choice of these two techniques) in an online usability study. One limitation of having the usability test conducted online, as opposed to having it as a physical workshop as was initially planned, was that there was no way to assess how long it took for individuals to understand and use the modelling technique. This would have provided a very useful data point in seeing how these techniques are perceived and understood, revealing the potential usefulness in helping to organise the collaboration between key players; a technique that is easy to understand and quick to adopt by people in the organisation should provide more collaboration support compared to one with a much steeper learning curve.

Despite this limitation, without any prior knowledge of the problem domain or of ecosystem modelling (as indicated by the discussions with members of the company during the interview process conducted prior to the usability study), all participants were able to grasp the fundamental concepts of the modelling technique that they chose to work with; at the same time, they were able to create a model that they considered to best represent the ecosystem (see examples in Figure 4.4 and Figure 4.3). Respondents were also asked whether the models they had just created would be understood by others in the company, and all of the respondents confirmed that they believed that to be the case, implying that the models can be considered a useful tool for enabling better collaboration between individuals.

A counterpoint to this opinion would be that two of the participants chose to add a significant amount of comment boxes to help explain the model that they had created (examples available in Appendix Figure B.7 and Appendix Figure B.8). The implication of this would be that the participants did not feel confident in the language notation of their chosen modelling language to express all of the concepts that they considered while creating the model. This is something that could be mitigated by training in using the modelling notation, although this would also require additional resources to be expended, the most important one being time.

To understand the why and the how of a particular technique choice, and to answer the research question, this process has been broken down into a number of points to assess and discuss:

1) the breakdown of who chose what technique: 1 business-oriented person chose UML, 4 technical-oriented people chose SSN,

2) the rationale behind their chosen technique (presented in Subsection 4.3.2), and

3) how their completed models express the ecosystem, which is discussed below.

The first point worth discussing is that one of the participants who chose to use UML was a Product Manager, explaining that "I know UML" as the main reason for their choice. This goes contrary to the idea that people would be more inclined to pick a modelling technique which is more fit to model their own perception of the ecosystem, with the more technically-inclined participants choosing UML. Unfortunately this was the only respondent that was part of management, therefore it is difficult to see whether this individual is an outlier with greater technical knowledge compared to everyone else in a similar position, or the norm for the company. Instead, it is possible to see that individuals within software development teams showed a preference for SSN, despite this being a completely new modelling technique that they had never used before.

In addition to this, the models that were created with SSN showed a good understanding of the way in which the elements are used to create an ecosystem model, with many of the models using most of the technique building blocks. Furthermore, comment boxes allowed respondents to explain their thought process behind how these elements are used, and some of the respondents made use of these boxes to explain more about their models. One observation that could be made around these resulting models is that the Company of Interest (COI) was not always the same as the case company, with one participant choosing to represent the case company as an intermediary instead. According to literature, the COI component represents the company under investigation, which delivers the Product of Interest (POI) (Boucharas et al., 2009). Based on this diagram (see Appendix Figure B.7), the respondent sees the case company as an intermediary, working together with the the Company of Interest to create the Product of Interest, implying a partnership in co-creation between the two.

All of the models created by respondents used the following concepts: COI, Intermediary, Customer, Supplier, some form of trade relationship, which are assessed

to be the main elements considered important by these participants in expressing the relationship that the various actors have in the ecosystem. To summarise, this assessment indicates that SSN can be a suitable method to capture complex relationships between ecosystem partners and provide a way in which different members of the organisation can collaborate and share information amongst one another.

The implications for practice based on the points above is that choosing a suitable modelling technique for a company might not be as straightforward as initially expected. There is perhaps a disconnect between what people expect to use a certain modelling technique for, and whether they are likely to use the same technique in a completely different setting. This is illustrated by developers still choosing SSN as more suitable for ecosystem modelling. Overall, the choice of one modelling technique or another was subjective to one's own understanding of the problem domain and experiences, but it also shows that introducing new modelling techniques that are not familiar to the participants can be just as beneficial as using a technique that is already familiar to them. Therefore, the choice of modelling technique should not be limited by the current capabilities of those in the organisation and any deficiencies can be mitigated through training (which the usability study provided in the form of short presentation videos), but other methods can also be employed.

5.5 Improving modelling techniques

This section answers *RQ3 In what way can an existing modelling technique be improved or adapted following company requirements?* As outlined in Section 4.4,three possible changes to SSN were presented to company participants, who were asked to assess which of these changes would be the most useful in representing software ecosystems.

The results show varying viewpoints on these changes. While all of the changes were considered useful to a certain degree, there were also respondents which were not as optimistic about these modifications, and there is no unanimous opinion on any of the possible improvements.

The respondents individually consider that in general, all of the changes provide some form of improvement but, at the same time, not all changes are compatible with one another (for example, the visual redesign of the components may include all components as boxes or the implementation of icons, but not both). Out of all the changes, the introduction of bi-directional arrows was the most valuable change according to three out of the seven respondents, as they stated that this change will give models more clarity especially in terms of collaboration. In terms of change 2 (dependency arrows), respondents believe that dependency arrows might aid in understanding the dependency relationship between two actors to a certain degree, but these dependency arrows can be represented by the previous change (directional and bi-directional arrows).

Moody (2009) presents the principles of visual notation, which helps to convey information from those who have extensive technical knowledge to even those who have little to no technical knowledge. Visual notations help to communicate knowledge

across a wide spectrum of individuals. The extent to which an image or symbol can be understood by its appearance is called semantic transparency – a primary focus for the analysis of the results presented in Section 4.4. In terms of the semantic transparency presented in change 2 and change 3, respondents do not believe that redesigning the components into uniform boxes aid in improving the modelling technique. Similar to the previous statement, icons might help make components more recognisable only to the extent where the icons represent semantic immediateness (meaning that individuals may infer the correct understanding conveyed in an image or symbol from its appearance alone) as stated by Moody (2009), and in theory, icons do as good of a job as geometrical shapes. While SSN modelling notation aligns with Moody (2009) as the design notation already provides design rationale for the components, the particular shapes used could be misunderstood, as was described above.

According to one respondent from the usability study, the flow component showed no visual direction resulting in confusion regarding how the actors were connected from a value exchange perspective. To interpret this notion more loosely in the context of the improvements that were presented, without a directional flow in the SSN diagram, novice readers may be unaware of the value exchange presented by the SSN component notation, resulting in misapprehension of the SSN model.

With these results, it is difficult to provide a definite answer to RQ3, as there is not enough data to make a conclusive decision regarding ways in which the SSN modelling technique can be improved. At most, what can be answered is that changes to SSN are perceived as generally positive, and that participants could see the use for many of the presented options, even if these opinions were not unanimous. Further data would be needed to properly confirm this assertion, with the possibility to test an improved SSN notation (incorporating the aforementioned changes) in practice. In addition, while these changes were initially assessed as potentially independent modifications, a combination of modifications might be the answer that provides the most value to ecosystem modelling, but would require an additional study to conclude this with a higher degree of certainty.

5.6 Modelling use cases

This section answers *RQ3.1 What possible use cases does the company find for this modelling technique?* The findings used to answer this research question are presented in Figure 4.17, where the respondents were asked to assess which use cases they saw for the presented modelling technique in the company. These possible answers had been pre-selected based on discussions and interviews with company members during the course of the study and also focused on the themes presented in Section 4.1.

To restate the answers that were the most prioritised among respondents, “Documenting business partners and relationships”, “Sharing ecosystem knowledge across the company”, “Developing new business strategies and strategic partnerships”, and “Visualising ecosystem changes” were considered to be the most popular possible

use cases for the modelling technique. This matches with what the company has in focus regarding ecosystem knowledge, prioritising documentation and knowledge sharing among individuals in the company.

The answer for RQ3.1 presents a number of possible use cases that the company can have for ecosystem modelling. This is based on the opinions of people working in the organisation, many of which had not used an ecosystem modelling technique before, nor were they familiar with how ecosystem modelling is performed.

According to Sadi and Yu (2015), SSN as a modelling technique presents a number of characteristics, all of which are in line with the answers that the respondents gave for possible company use-cases. The first criteria is that the focal viewpoint of SSN is valuable at the business and inter-organisational level where the technique presents the various entities inside the software ecosystem which includes collaborators and their relationships (Sadi & Yu, 2015). This matches the option chosen by respondents regarding supporting documenting business partners and their relationships, as well as developing new business strategies and strategic partnerships.

Another criteria that the SSN modelling technique encompasses relates to its usability features: SSN is considered a mature technique with support for qualitative analysis, provides a good representation of a software ecosystem, and has been created with users in mind (Sadi & Yu, 2015). With ample support for analysis and good visual representation of an ecosystem, SSN becomes a technique which can facilitate sharing ecosystem knowledge throughout a company. The fact that respondents were able to quickly pick up the basics of the technique during the usability study, along with the assessment that this technique might be useful in the future to the company, only serves to confirm these points and turn them from theory into practice.

6

Conclusion

During the course of this study, the attempt was to investigate how a software company in the automotive domain captures and perceives software ecosystems, and whether ecosystem modelling techniques can be employed to help them in representing these ecosystems.

To conduct this investigation, interviews with three different types of stakeholders were conducted, which set the foundation for understanding what the company understood through software ecosystems. Results showed that there was no clear vision between members of the organisation: software ecosystems and their boundaries were subjective to each individual, and there was no clear way to capture or represent them in the company. Two perceptions were discovered: the management perspective, looking at ecosystems through a very broad lens, focused on partnerships and collaborations with external companies; and the technical view, which saw ecosystems as something that could also be limited to within the case company itself.

Given these two diverging perceptions, two existing modelling techniques were chosen based on literature and on the discussions with the study participants. The two techniques, UML and SSN, were assessed against each other, with the participants being asked to model the ecosystem that they are part of. The results indicated that, while more were familiar with UML, many participants chose to use SSN instead, and their models showed an understanding of the modelling technique even if they had no prior experience or use of it before this study.

Three improvement suggestions were presented to individuals working in the company, with the changes ranging from different visual representations of the modelling technique, to introducing different types of relationship flows between actors in the ecosystem (inspired by UML notation, or by the observations made by the study participants). Even after presenting these changes to those working in the company, the results were inconclusive, and while participants agreed that improvements would be useful for the modelling technique, there was no conclusive view of what the most useful improvement would look like.

Finally, participants also identified what ecosystem modelling could be used for; possible use cases in the company are directly associated with the main findings from interviewing participants of the study: ecosystem modelling can help in improving the collaboration, knowledge sharing and identifying new business opportunities. These findings are consistent with the views that participants had when interviewed

on ecosystems, and the researchers have assessed that SSN would be a suitable modelling technique to fulfil these use cases.

6.1 Future work

This study was conducted during the Spring of 2020, amidst the COVID-19 pandemic, which forced most of the participants of the study and the researchers to conduct the study in a remote manner. This affected the amount of individuals from the case company who were available to participate in the study, created difficulties in collecting relevant data, affected companies in the automotive domain in particular, and as a result, limited the scope of the overall study.

Given the limitations of the study, there are many ways in which the findings can be refined and built upon. The study was conducted under the premise that there is a limited amount of information on how practitioners utilise software ecosystem modelling techniques and the role of ecosystems in a software company in the automotive industry.

A first area of study that can be pursued is identifying a set of concrete improvements for the SSN modelling technique. The present study identified a number of starting points, but could not find a conclusive answer to the question of which improvements would make the model better due to the limited amount of data that was collected. Another study could expand on these improvement suggestions, and either combine them into new sets of changes (together with the suggestions that the participants also offered), or assess the same changes once again to be able to draw a more varied range of conclusions.

In addition, another way to improve the study would be to apply the modelling techniques and improvements presented in this paper in a different software company (also in the automotive industry) to see whether the findings are consistent between studies and if they can be further generalised to other companies in the same field. Furthermore, the study can be repeated in the case company in the efforts to cross-analyse this study with future findings based on additional data points.

A second area of study would be a more detailed examination of how automotive disruptions have an effect on software ecosystem representations, and how modelling techniques can help in visualising such changes and guiding relevant decisions in the field.

It is the researchers' hope that this study provides a good baseline for conducting further investigation in related areas, and that the findings can create interest in uncovering more research materials in these fields.

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A

Appendix 1 - Iteration 1

A.1 Interview Questions

Background for all These questions will be asked in order to get context on the participant.

1. So, can you tell us about your position in the company?
2. What do you do and what are your responsibilities in the company?
3. How long have you worked in the company?

Internal interviewees Questions for those working inside the company.

1. What team or teams do you work with?
2. Can you give us an example of how you work within a team?
3. Can you describe your relationship you have with other teams?
4. Ecosystem Questions:
   (a) Are you familiar with the term ecosystems, more specifically software ecosystems?
   (b) **If yes:**
      i. Can you tell us more about how you work with them?
      ii. Would you say that everyone you work with is aware of these software ecosystems?
      iii. How are you aware of this ecosystem? Do you have diagrams, models, or formal specifications regarding it?
      iv. What do you keep in mind the most when working with the ecosystem?
      v. Are there any guidelines that you follow?
   (c) **If no:**
      i. Maybe you have a different definition of software ecosystems or maybe you have a different interpretation of software ecosystems. But to simplify the definition, software ecosystems are simply the set of organizations interacting with one another that are linked through

software or software related components. Various stakeholders are involved and their collaboration is marked through the interactions they have with one another along with the activities or resources that flow between their relationships. A software ecosystem provides a clear view of the structure of collaboration.

ii. Can you briefly describe the software components and services that you and your team work with?

iii. Can you identify several stakeholders outside of the company that is in collaboration with your team or with WirelessCar?

A. Can you describe the relationships between these stakeholders with WirelessCar?

iv. Is there any documentation or guidelines in WirelessCar that describes these relationships? For example; are there diagrams? Is there a person you talk to regarding this?

v. How do you share the knowledge about what your collaboration looks like and with whom you interact within your team and those outside the team?

vi. Was there some form of formal training/documentation that you read or saw to understand these elements, or did you just pick them up as you went along? Do you feel like others in the company have the same perception as you do about these (relationships between actors/stakeholders)?

vii. How do you keep track of changes in these collaboration?

viii. **Architect:** As an architect, how do you present the ecosystem to the other relevant people and teams involved?

ix. Are there any documents/diagrams showing the type of data and data flow that is exchanged between teams within the ecosystem and outside the ecosystem?

x. How much of an impact do inner and outer stakeholders and their relationships have on decisions within the company?

xi. How do you keep track of your external and internal stakeholders and make sure that they are not ignored when making important decisions?

5. Lifecycle Questions & Business Model:

(a) With more users using cars instead of owning them, have you noticed a change in the types of systems that you have to develop?

(b) **Developers:** When developing software components/services, are you presented with a broad overview of the problem domain, or do you simply solve a very specific and narrow task?

(c) Since there are different teams working on different solutions in the company, would you say that the software and services are part of a common product or environment, or is every part independent from one another?

(d) Is there overlap between the services that are developed in each team?

(e) **Managers/Architects:** Within the automotive domain, car dealers are currently finding ways to keep up with the changes in the area of connected services.

i. What services or products do you have that would help car dealers in keeping up with the car sharing market?

ii. Is WirelessCar currently working on new solutions that will help the collaboration between WirelessCar, the OEMs and the car dealers?

(f) In your opinion, what sort of impact has the sharing market had, or will have in the near future?

(g) **Managers/Architects:** Do you think that the region (USA/China/Europe) affects the way in which users consume your services?

(h) How do you determine how to focus business decisions?

External interviewees Questions for those working outside the company.

1. Can you give us an overview of your business relationship with WirelessCar?
2. Ecosystems:

(a) Are you familiar with the term ecosystems, more specifically software ecosystems?

(b) **If yes:**

i. Can you tell us more about how you work with ecosystems within the automotive domain in relation to WirelessCar?

ii. Would you say that everyone you work with is aware of these software ecosystems?

iii. How are you aware of this ecosystem? Do you have diagrams, models, or formal specifications regarding it?

iv. What do you keep in mind the most when working with the ecosystem?

v. Are there any guidelines that you follow?

(c) **If no:**

i. Maybe you have a different definition of software ecosystems or maybe you have a different interpretation of software ecosystems. But to simplify the definition, software ecosystems are simply the set of organizations interacting with one another that are linked through software or software related components. Various stakeholders are involved and their collaboration is marked through the interactions

they have with one another along with the activities or resources that flow between their relationships. A software ecosystem provides a clear view of the structure of collaboration.

ii. Can you identify several stakeholders outside of the company that is in collaboration with your team?

iii. How do you share this knowledge and information with those within your team and those outside the team in regards to this collaboration?

iv. What sort of data do you exchange with WirelessCar, both inputs and outputs? Data in this context could mean from specifications, requirements, models, APIs, and so forth?

A. Is there a formal representation of this data in the form of diagrams or documents?

(d) As part of our study, we want to focus on the software ecosystem involving car dealers in order to define our study. We understand that dealers are actively finding ways to align themselves with the transformation process occurring within the automotive domain;

i. How do you see your business relationship with them changing in this context?

ii. Are there current strategies in place that will help with the collaboration with car dealers? What value do you think dealerships have in this relationship and within the connected service space?

(e) This is a rather broad question, but what sort of impact has the sharing market had, or will have in the near future?

(f) Keeping the car dealers in mind, do you believe that this will change the way in which your partnership with WirelessCar functions or change the way you work with WirelessCar?

External interviewees - Car dealers Questions for those working outside the company, in particular car dealerships.

1. What is your business relationship with OEMs? Can you give us an example of how this relationship works?
2. Can you explain a bit about your business model and how a regular day is carried out in a dealership?
3. Would you say most of your customers/clients are companies or private individuals?
4. Does [your company] provide car rental or car sharing options?
5. What is your business relationship with WirelessCar?
6. Do you use their services for fleet management? Can you give us a few examples of these services and how you use them?

7. What other stakeholders do you consider to be the most relevant in your business collaboration between your company, OEMs and WirelessCar?
8. Can you give an example of the vehicle lifecycle process from the OEMs being the point of origin all the way to your dealership? What is the journey of the car from concept to when it leaves your dealership?
9. How do you share this knowledge and information with those within your team and stakeholders outside of the company?
10. What sort of data do you exchange with WirelessCar, both inputs and outputs?
    (a) Is there a formal definition of this data in the form of diagrams or documents?
11. With more users using cars instead of owning them, have you noticed a change in the types of systems/services that you require?
    (a) What do you believe will be the role of dealerships if car sharing increases instead of users purchasing?
    (b) Will this affect the way in which you collaborate with your current partners?
    (c) Will new partners be required?
    (d) What prospective strategies do you foresee in the future?
    (e) Are there any other services that will help your companys business prospects in the future?

A.2 Interview Questions mapped to research questions

Table A.1: Mapped interview questions - Background and General Questions

No.	Question	RQ 1	RQ 1.1	RQ 1.2
1	So, can you tell us about your position in the company?			
2	What do you do and what are your responsibilities in the company?			
3	How long have you worked in the company?			
4	What team or teams do you work with?			
5	Can you give us an example of how you work within a team?			
5a	Can you describe your relationship you have with other teams?			
3	How long have you worked in the company?			
4	What team or teams do you work with?			

Table A.2: Mapped interview questions - Ecosystem

No.	Question	RQ 1	RQ 1.1	RQ 1.2
6	Are you familiar with the term ecosystems, more specifically 'software ecosystems?'	x		
If yes 6a	Can you tell us more about how you work with them?	x		x
6ai	Would you say that everyone you work with is aware of these 'software ecosystems'?		x	
6aii	How are you aware of this ecosystem? Do you have diagrams, models, or formal specifications regarding it?	x	x	
6aiii	What do you keep in mind the most when working with the ecosystem?		x	x
6aiv	Are there any guidelines that you follow?	x		x
If no 7	Can you briefly describe the software components and services that you and your team work with?	x		
8	Can you identify several stakeholders outside of the company that is in collaboration with your team or with WirelessCar?	x	x	
8a	Can you describe the relationships between these stakeholders with WirelessCar?	x	x	
9	Is there any documentation or guidelines in WirelessCar that describes these relationships? For example; are there diagrams? Is there a person you talk to regarding this?	x		x
10	How do you share the knowledge about what your collaboration looks like and with whom you interact within your team and those outside the team?	x	x	
11	Was there some form of formal training/documentation that you read or saw to understand these elements, or did you just pick them up as you went along? Do you feel like others in the company have the same perception as you do about these (relationships between actors/stakeholders)?	x		x
12	How do you keep track of changes in these collaboration?			
13	Architects: As an architect, how do you present the ecosystem to the other relevant people and teams involved?	x		
14	Are there any documents and or diagrams showing the type of data and data flow that is exchanged between teams within the ecosystem and outside the ecosystem?	x		x
15	How much of an impact do inner and outer stakeholders and their relationships have on decisions within the company?		x	
16	How do you keep track of your external and internal stakeholders and make sure that they are not ignored when making important decisions?	x	x	x

Table A.3: Mapped interview questions - Lifecycle

No.	Question	RQ		
		1	1.1	1.2
17	With more users using cars instead of owning them, have you noticed a change in the types of systems that you have to develop?			x
18	Developers: When developing software components/services, are you presented with a broad overview of the problem domain, or do you simply solve a very specific and narrow task?			x
19	Since there are different teams working on different solutions in the company, would you say that the software and services are part of a common product or environment, or is every part independent from one another?		x	x
20	Is there overlap between the services that are developed in each team?		x	
21	What services and or products do you have that would help car dealers in keeping up with the car sharing market?	x		x
22	Is WirelessCar currently working on new solutions that will help the collaboration between WirelessCar, the OEMs and the car dealers?	x	x	x
23	In your opinion, what sort of impact has the sharing market had, or will have in the near future?		x	
24	Managers/Architects: Do you think that the region (USA/China/Europe) affects the way in which users consume your services?			x
24a	How do you determine how to focus business decisions?		x	x

Table A.4: Mapped interview questions - External stakeholder

No.	Question	RQ 1	RQ 1.1	RQ 1.2
25	Can you give us an overview of your business relationship that you have with WirelessCar and how can you outline what this relationship looks like?			
26	Are you familiar with the term ecosystems, more specifically 'software ecosystems?'	x		
If yes 26a	Can you tell us more about how you work with ecosystems within the automotive domain in relation to WirelessCar?	x		x
26ai	Would you say that everyone you work with is aware of these 'software ecosystems'?		x	
26aii	How are you aware of this ecosystem? Do you have diagrams, models, or formal specifications regarding it?	x	x	
26aiii	Are there any guidelines that you follow?	x		x
27	Can you identify several stakeholders outside of the company that is in collaboration with your team?	x	x	
28	How do you share this knowledge and information with those within your team and those outside the team in regards to this collaboration?	x	x	
29	What sort of data do you exchange with WirelessCar, both inputs and outputs? Data in this context could mean from specifications, requirements, models, APIs, and so forth?	x		
29a	Is there a formal representation of this data in the form of diagrams or documents?	x		x
30a	How do you see your business relationship with them changing in this context?		x	
30b	Are there current strategies in place that will help with the collaboration with car dealers?		x	
30c	What value do you think dealerships have in this relationship and within the connected service space?		x	
31	This is a rather broad question, but what sort of impact has the sharing market had, or will have in the near future?			
31a	Keeping the car dealers in mind, do you believe that this will change the way in which your partnership with WirelessCar functions or change the way you work with WirelessCar?		x	

Table A.5: Mapped interview questions - Car dealership

No.	Question	RQ 1	RQ 1.1	RQ 1.2
32	What is your business relationship with OEMs? Can you give us an example of how this relationship works?			
33	Can you explain a bit about your business model and how a regular day is carried out in a dealership?			
34	Would you say most of your customers/clients are companies or private individuals?			
35	Currently, does your company provide car rental or car sharing options?			
36	Can you briefly explain what is your business relationship with WirelessCar?			
36a	Do you use their services for fleet management? Can you give us a few examples of these services and how you use them?	x		x
41	With more users using cars instead of owning them, have you noticed a change in the types of systems/services that you require?			x
41a	What do you believe will be the role of dealerships if car sharing increases instead of users purchasing?		x	
41b	Will this affect the way in which you collaborate with your current partners?		x	
41c	Will new partners be required?		x	
41d	What prospective strategies do you foresee in the future?			x
41e	Are there any other services that will help your companys business prospects in the future?			x

A.3 Thematic coding - Quote mapping

A.3.1 Theme Quotes: Understanding Software Ecosystems

1) "I can be more familiar definitely, if you can explain, yeah." (Software Developer)

2) "It could be like ecosystems in the sense of making software, developing it, how it goes around, but it could mean a lot of things. Its so subjective." (Software Developer)

3) "Yes, I think so. If you mean more or less frameworks and such. Frameworks and yeah." (Architect)

4) "I dont think so, no." (Architect)

5) "A bit. Then you need to enlighten me. So in terms how companies are working together, for some years ago everyone was providing their own plat-

forms...But by providing isolated services you really decouple technology and you can bring in co-creation together with others. So, this is why we provide services to our customers and they are the makers of the connected car platforms. So, we see how different partners in the ecosystem provide software, is it as a product, is it as a service, and who is the owner of the roadmap." (Product Manager)

6) "Familiar, well yes, but not so in deep. It is a very fluffy word that can mean a lot of things." (Product Manager)

7) "Yeah, I'm familiar with the term ecosystem, [...] both of us have different understandings and we don't talk about the same thing." (Collaborator - Portfolio Manager)

A.3.2 Theme Quotes: Perception of Software Ecosystems

1) "when you see those diagrams and when you see the documentation you might know what they are, but you might not know how they are functioning internally," (Software Developer)

2) "So it's very hard to actually bring everyone under one umbrella. But if that was the case, things would have been very nice." (Software Developer)

3) "you need that overview to understand why this change needs to be put into place, so it's like a mix of both worlds." (Software Developer)

4) "I think so, yeah. I mean, I cannot speak from the point of view of the people who work closer with the customer" (Software Developer)

5) "we mostly work in the Java domain, Java language, and I mean, that's a very solid knowledge in teams, but the Java ecosystems of frameworks and tools, if I interpret the ecosystem as the frameworks and tools" (Architect)

6) "So it's very much in the heads of many people, but its spread out among of many people." (Architect)

7) "its the same most every team we have the same customer interfaces and the manger all the teams know him because it's so small. So it's very different from different program" (Product Manager)

8) "So in that sense we are partners in creation with the customer. And in some cases we are also covering partners intelligence in everything, so it's everything." (Product Manager)

A.3.3 Theme Quotes: Stakeholder Awareness

1) "Outside of WirelessCar? Yeah, I don't work with them, directly." (Software Developer)

2) "It's very seldom that I have some communication with external companies." (Software Developer)

3) “all the impact. I mean, they decide everything, right? They are the stakeholders.” (Software Developer)

4) “We also have external stakeholders within the Wireless program, also, for example TechLab, from the top floor, we use things from them, so that ends up having, that ends up making them some sort of an external stakeholder, but they are still within Wireless” (Software Developer)

5) “They have quite some impact yeah, for at least for the specific delivery. Not the WirelessCar in general, of course, but for our delivery, they have a lot of knowledge about the setup and usually give a lot of input.” (Architect)

6) “We have mostly the PI planning, I would say, where we discuss dependencies and everything, because the customer, our end customer, [Company], is here when we have planning, so they will be available for input, and then of course we discuss with TechLab and Connect what we want to prioritize each PI” (Architect)

7) “Most importantly for this [cloud-computing platform company] I would say is a big player, then of course, not for this particular application, but if we look in general of course we have all our customer programs, everyone involved there” (Architect)

8) “the customer, that is the primary stakeholder. And then that is this company I talk about, the [company name].” (Product Manager)

9) “independent depending on the program, so we have internal stakeholders, I mean we have in the delivery organization we have defined roles, responsibilities that work with the external, and we also have sales and marketing and they have their stakeholders at the customers. So, it differs with what role you have.” (Product Manager)

10) “the development teams, they have their meetings with customer and their interfaces and me and the key account manager we have ours and of course, senior management relationship, that is also important to have those kinds of relationships and stakeholders and that” (Product Manager)

11) “we were just talking about these stakeholders, I’m sure you are familiar with our PI planning, so we want to have a close relationship, we really want to invite the customers here when we have the PI planning, so they are here, involved, participating and discussing.” (Product Manager)

12) “we are actually just acting as advisors and partners, providing insight whether the customers should choose Azure or AWS or Google, or however. So in that layer we are partners who have done everything and we want to help our customers” (Product Manager)

13) “on the tech giant level it’s [big tech giants] to name the two most important, and together with them we are building the IoT platform” (Product Manager)

14) “we work together with partners within automotive safety and create a service like driver behaviour, so together with research from another company we look at how would be the safest way to drive and together so we provide this end to

end service to the customer, but down beneath is co-creation with a partner." (Product Manager)

15) "we work with [telecommunications company], which is an ecosystem partner, we don't develop anything together, but we see that we are integrated with each other, so they can actually broadcast the services in China." (Product Manager)

16) "our customer, because our customer, as we are living in a, we as a fleet organization our main customer is always a very big company, so if we look for example on our rent-a-car customer, Hertz, Sixt, Avis, Europcar, they are ordering every year a lot of vehicles" (Collaborator - Portfolio Manager)

17) "We have the strategic advantage that we are building the car, there is no need for 3rd party hardware, we can provide the data right out of cars, so when we talk to WirelessCar, we want with our partner WirelessCar a collaboration that they enable us to generate data within our vehicles which we can then modularize and send to whoever wants that data, for example a rent-a-car company" (Collaborator - Portfolio Manager)

A.3.4 Theme Quotes: Documenting/Guidelines of Software Ecosystems

1) "No. [...] There is no instruction. " (Software Developer)

2) "Definitely not, no. Or at least I am not aware of them." (Software Developer)

3) "We talk about it in Scrum meetings." (Software Developer)

4) "technical diagrams, how we interact, our components [...] Yeah, of course, yeah, of course." (Software Developer)

5) "And its vital for us to document all of this because if for example, if someone new joins our team or the Wireless program in general, they must know how we are collaborating with them" (Software Developer)

6) "So it becomes very vital for us. And we have documentation for such." (Software Developer)

7) "It starts off with an overview, of course, but it goes deep down, but I think it's, how should I say this, it's well-documented in the sense that someone with a very high technical knowledge and a very low technical knowledge both can understand it." (Software Developer)

8) "We have a tech radar where the frameworks and tools and everything is mapped in different stages [...] sothen we have like a diagram, that what works, a tech radar diagram" (Architect)

9) "we have always meeting notes, with all decisions and topics and everything that we have discussed" (Architect)

10) "Probably, but I don't know." (Architect)

11) “it’s per service based, and it’s very dependent on the program it’s in, and also the service within the program how it’s documented and how its described” (Architect)

12) “So we are not moving in the same direction between the different programs and we have architecture forums where we can bring up architectural discussions that involves all programs” (Architect)

13) “there is one thing that we may lack at WirelessCar, that is documentation and processes written, we have good enough, but it’s not too easy to take part of other programs” (Product Manager)

14) “So maybe in the program we keep track of what kind of meeting we have and we also have minutes and so on.” (Product Manager)

15) “theres one pretty nice picture that we could send to you, there is one picture describing ecosystem and what kind of partners we do have within the different sort of abstraction layer” (Product Manager)

A.3.5 Theme Quotes: Sharing Software Ecosystems

1) “we usually have Slack channels where we have everyone together and its open and public and everybody can see what’s going on” (Software Developer)

2) “then if there’s something extraordinary we will talk about it in the morning in our Scrum meetings, but there is no systems” (Software Developer)

3) “No, there is no training for this. I think it’s kind of expected of you that you will just figure it out.” (Software Developer)

4) “We talk about it in Scrum meetings.” (Software Developer)

5) “Confluence is just like a store for keeping all the information. But in Confluence we have documentation and diagrams for different, as you said, stakeholders” (Software Developer)

6) “the communication between the team members is very helpful there. So some knowledge still remains tacit, it passes from word to word, but it sometimes never lands up in the documentation, so for me I had to rely both on the documentation and people making me understand some things” (Software Developer)

7) “You may come across people creating different diagrams to represent different things, but they could all be, you know, collectively expressed in a very formal way, but sometimes people choose not to, because knowledge differentiation and many things” (Software Developer)

8) “you had an architect in each team and this person would have the overall picture, a big one, and then they would translate it into requirements and tasks” (Software Developer)

9) “Mainly through program stand-ups where all the teams get together, go through major changes in the ecosystem. And then we have the WirelessCar

architecture meeting where all the lead solution architects gather to discuss future technology in the ecosystem, what to use." (Architect)

10) "then it's more informal, like information session, once every sprint we have this stand-up for all the teams and so on to share" (Architect)

11) "the work we do in my team, with reviews, thats one of these opportunities where we can go talk to one of the customer programs" (Architect)

12) "it goes through the product owner, one key person to spread what we are doing, and through Reviews, that I also talk about, we also spread what we are doing, and we also we have recently started this community of practices within certain technical areas" (Architect)

13) "we are calling for meetings on them for my team, so we are the ones driving a few of those" (Architect)

14) "it becomes more almost personal contacts rather than just formal business contacts, and you use those when you communicate as well" (Architect)

15) "my feeling is that we very often draw it out from the start every time we need to discuss something" (Architect)

16) "there is one representative from each program where we can highlight things that we feel are going in the wrong direction" (Architect)

17) "we are quite like, separated in each program. We have different architectures more or less in each program, so the common architecture for the connected service is of course the WirelessCar Connect Common, but each program has their own more or less microservice or architecture and where they host their solution and everything, so it's not really decided on that level" (Architect)

18) "I guess up here? (points to head)" (Architect)

19) "I don't know, I usually whiteboard a lot, but not the collaboration part, that's more the technical part, I guess. I dont know, I think it's very informal, I don't know." (Architect)

20) "So it's very much in the heads of many people, but its spread out among of many people." (Architect)

21) "Between the programs we have these different forums where we meet and share both knowledge and also challenges so we could help each other" (Product Manager)

22) "internally within the program, we have regularly collaboration different setup for us. I mean it could be in the teams when they are working, they constantly actually working with sharing knowledge. It's a day to day, daily work" (Product Manager)

23) "if we see that we need, oh we need to have maybe a lunch talk to spread the information we set up that up at WirelessCar so everyone can know. So, we really try to see how is the best way to reach out to this kind of knowledge sharing." (Product Manager)

24) “We are also having these hubs, these architectural hubs thar are common for all of WirelessCar and all major architectural changes go into that forum.” (Product Manager)

25) “this is a challenge, but we always try to share that knowledge” (Product Manager)

26) “My preference is that I like the visual presentation and information because it’s easier to quicker understand and get a higher understanding. So I think that is absolutely. I think that is a good thing. And also when you are new, you come in a new program it really, really helps to quicker get efficient and start to work if you understand the interfaces and the way of working. So yes, absolutely.” (Product Manager)

27) “when you are a developer sitting in a team you don’t have as much information actually and the world gets smaller. So I think it would be really good if you could visualize that, because then it’s accessible for everybody.” (Product Manager)

28) “we try to have a WirelessCar way of working that sets the framework, so we have a basic way of working and roles, but then it’s dependent on the customers, we want to meet the customers way of working and efficient way and meet their stakeholders so that can depend on how they set up our internal stakeholders.” (Product Manager)

29) “the product management they are working a lot with that to understand different customers needs for example fleet, and that can also be B2C when it’s a specific service, then its really, really also good to have this cross-program knowledge, how do we develop and maintain, but also provide new services.” (Product Manager)

30) “is actually the most important thing with WirelessCar, to build this common understanding and knowledge and competence on how do we build connected services in the best way, and we use that in all programs, and at the same time manage to do the customization. That creates really strong ecosystem or solution.” (Product Manager)

31) “Not as an organization chart or something. We have just our interfaces listed. In our case its so different because Volkswagen is a huge program and they have so many customer interfaces, I think they actually have that, what you are describing” (Product Manager)

32) “My preference is that I like the visual presentation and information because it’s easier to quicker understand and get a higher understanding. So I think that is absolutely. I think that is a good thing. And also when you are new, you come in a new program it really, really helps to quicker get efficient and start to work if you understand the interfaces and the way of working. So yes, absolutely.” (Product Manager)

33) “within my organization I have an appointed partnership manager. So [partnership manager] is actually the one having the whole list of partners within the different areas. And he is also helping the sourcing with really bringing

up all new suppliers and then sourcing is focused on which partners to buy consultant services or tools and so on. But [partnership manager], he is really the one in collaboration with product managers, really keeping everything together, which are tools partners, who are technology partners who we actually create stuff with„ who are just simple suppliers, we don't create anything but they are strategic enough. You know to be enterprise we need to have refunds and whatever, and of course, who are bringing in new business. So, he is the only one who is all over the place." (Product Manager)

34) "we need more people and partnerships." (Product Manager)

A.3.6 Theme Quotes: Collaboration

1) "we can have this very tight collaboration and then in this very tight collaboration, it's undoubtful who you want to speak with" (Software Developer)
2) "you just have to have experience in the company and kind of understand. You have to know who to talk with, thankfully theres not many chains of telling one person to tell another person" (Software Developer)
3) "if there's a problem there, we have to communicate it" (Software Developer)
4) "Im constantly in meetings with TechLab." (Software Developer)
5) "Confluence is just like a store for keeping all the information. But in Confluence we have documentation and diagrams for different, as you said, stakeholders" (Software Developer)
6) "Yeah, Draw.io, exactly. And we store it in Confluence," (Software Developer)
7) "Jira is for keeping track of tasks and all of that" (Software Developer)
8) "more freely interpreted by each program and team how to do each stand-up. It's quite loose." (Architect)
9) "we are working on having a more coherent and more general working model, definition of done and everything like that" (Architect)
10) "the programs in the company they are quite separate, as far as I understand and can see" (Architect)
11) "I would say that its pretty much silos, unfortunately" (Architect)
12) "between the customer programs there is not that much collaboration as such. The collaboration happens more between the programs and TechLab, where we are, and then TechLab helps with collaboration between the customer programs to some extent" (Architect)
13) "we often gather around, coming from TechLab at least, where we can see a little bit what's going on in different programs, we can see that we may not be on the same track with everyone" (Architect)
14) "internally we use various tools, collaboration tools where the whole team can access, our developers can access and when we are facing the customer, we

also have certain collaboration tools where relevant people get access to, so everyone is working out of one tool." (Collaborator - Portfolio Manager)

A.3.7 Theme Quotes: Impact of automotive transformation process

1) "I feel like two years is not enough time to notice a difference in this" (Software Developer)
2) "I dont like to speculate." (Software Developer)
3) "the car never changes, but the software inside it does" (Software Developer)
4) "the software never becomes centralized anymore, it has to become decentralized in some way so you can entertain a lot of people" (Software Developer)
5) "Companies will end up making more money on a single car. Because you know that that single car might have multiple sources of income." (Software Developer)
6) "all I need to do is tweak my application inside the car to entertain your needs and your needs, as I said, the car remains the same, all that changes is the software in it. And that's easier to do rather than changing the hardware of the car" (Software Developer)
7) "every region has its own things are valued differently in different places, in different regions." (Software Developer)
8) "that's the power of software, you can scale it and it's easier than scaling hardware." (Software Developer)
9) "it's more API driven development, we shifted more effort on robust APIs instead of having fancy portals" (Architect)
10) "I would say we are not the whole way there yet, but I think we are more and more talking with, we want to build more isolated services that we can offer to a broader amount of vehicle groups" (Architect)
11) "long term we will definitely see more and more car, people dont want to necessarily to own their car and their problems with a car" (Architect)
12) "you can see the car sharing as a way forward, where you can have the flexibility you need of having a car, but you only have it when you need it, you don't have to take all the problems with you" (Architect)
13) "We have noticed from customers an increasing demand when it comes to car sharing services" (Product Manager)
14) "we will absolutely see major impacts on WirelessCar and our customers. It's another behaviour and how exactly I mean that is the services again. It will be an increased request for services where you support this." (Product Manager)
15) "the future of car sharing we would say that rentals are actually car sharing providers on a very sort of traditional way." (Product Manager)

16) “it’s not actually a service they even buy, there are very limited and very small margins in that kind of digital services,” (Product Manager)

17) “I do believe digital services will make all the impact. Cause if they don’t have the digital services sharing will really be impossible and until now digital services have been a sort of makeup” (Product Manager)

18) “It has to do a lot with mobility.” (Product Manager)

19) “So these kind of setups need to be really local, otherwise you can’t make people adapt. So for each city, each country, each region these kind of solutions need to be provided.” (Product Manager)

20) “the connected car market and however you want to call it has a very big impact in the future because I think if you take a normal vehicle, the strategic advantage [...] is not anymore with those hard facts such as the size of navigation, fuel range, it’s over connected services” (Collaborator - Portfolio Manager)

A.3.8 Theme Quotes: Focusing business decisions for the connected aftermarket

1) “Some parts are independent, and some parts are the same” (Software Developer)

2) “its not the same product or solution.” (Software Developer)

3) “There are some projects in our program that can be completely standalone. Some. However, others on the other hand are interdependent.” (Software Developer)

4) “Collaboration because that’s the way they will grow, and thats the way they will catch the market, capture the market in some way.” (Software Developer)

5) “OEMs can still do their own things, but as long as if they see a bigger picture in collaboration, then why not? But it also depends on their business process and business analysis and everything. But I mean, overall if you want to change, if you want to grow, you have to collaborate, at least to some point.” (Software Developer)

6) “then of course, as more and more programs use the general WirelessCar Connect products, then of course we will be dependent on each other, of course. Because if you want a change on the Connect service from one customer, it will probably propagate to another customer.” (Architect)

7) “I would try to get input from Connect, because I really believe in the move to Connect services, the general WirelessCar Connect services, and the roadmap from those services and try to lead our end customer to use those services more and more.” (Architect)

8) “I would say we are not the whole way there yet, but I think we are more and more talking with, we want to build more isolated services that we can offer to a broader amount of vehicle groups” (Architect)

9) “You need to continue using what you have and build on top of what you have already. When you’re building something new it’s easier to go towards a certain direction directly but changing what you have takes some time.” (Architect)

10) “But that depends on what type of business you are making. Because now we are working a lot on fleet, business to business, and we are the only program that is focusing on that, because the other programs is B2C.” (Product Manager)

11) “should have, a WirelessCar I call it framework, but architectural strategies that we should base our design on” (Product Manager)

12) “is actually the most important thing with WirelessCar, to build this common understanding and knowledge and competence on how do we build connected services in the best way, and we use that in all programs, and at the same time manage to do the customization. That creates really strong ecosystem or solution.” (Product Manager)

13) “we able to develop the services with help of different APIs to meet those kind of demands.” (Product Manager)

14) “We try to have this common services that we want to use and then customize them. So, it’s different. Some cases it’s really 100% customized, but one of the major and biggest goals in 2020 is to accelerate the usage of WirelessCar products.” (Product Manager)

15) “Today we have a way to go actually, we are not there yet, so it’s lot of customized services in all the programs. But we are getting there and it’s very clear where we want to go.” (Product Manager)

16) “It takes time, like all changes does. Because we already see that maybe it takes more time. But one example is, now I think while Im talking, but the B2B, I mean we noticed now that all customers are talking about B2B. We see that that is the future. That is one very clear trend because we don’t think everybody will own their own car, it will be sharing, and it will be fleets and it will be a must to handle those fleets in an efficient way. Fleets, that is the future, I think” (Product Manager)

17) “the new quite new initiative called WirelessCar Discovery, and that is our sort of goal to enriching our services” (Product Manager)

18) “we would broadcast to a number of partners out on the market to see who are having good intelligence within these areas. So that is one way of approaching.” (Product Manager)

19) “The other one is being a sort of enterprise partner with [big tech companies] in really setting the creation and the solution for the automotive cloud. And of course we are in a number of organizations working with security and digital key, a number of organizations where we are a driver in that sense.” (Product Manager)

20) “So in order to make that happen, we really need to on a very low, or I would

say technology base level, need to set a fleet-level approach in connecting the car." (Product Manager)

21) "it's based on a number of different solutions totally dependent on what the customer wants, whether they just want to provide a car to rentals or they actually want to manage the car themselves or they want to act as mobility providers" (Product Manager)

22) "I would say we do have a number of different solutions for different customers depending on the needs, but in the sort of kernel it's about making the car connectivity fleet-ready." (Product Manager)

23) "That first of all we need to be the preferred partners with our customer, so its a matter of advising" (Product Manager)

24) "we are built up that way and the stakeholders for the different programs they are very independent depending on the program" (Product Manager)

25) "We try to have this common services that we want to use and then customize them. So, it's different. Some cases it's really 100% customized, but one of the major and biggest goals in 2020 is to accelerate the usage of WirelessCar products." (Product Manager)

26) "we provide them with digital services" (Collaborator - Portfolio Manager)

27) "seen it in more shift to APIs instead of portals" (Architect)

28) "Traditionally it has also been Volvo that has been part of our network setup and how we sort of, how we work, since we have been part of Volvo" (Architect)

29) "I would say we are not the whole way there yet, but I think we are more and more talking with, we want to build more isolated services that we can offer to a broader amount of vehicle groups" (Architect)

30) "We want to lead at WirelessCar, and I think we do that in many different perspectives. But when it comes to B2B, [company name] is actually leading." (Product Manager)

31) "So this is for us a sort of first key to unleashing the potential to sharing the mobility and that need is already here, already today. It's not a future need, it's a now need." (Product Manager)

32) "foremost we need to be the advisors who empower and accelerate the customer vision. And of course, we want to contribute to the sustainable mobility, so if we don't pave the road by this stuff, it won't happen." (Product Manager)

33) "Now we need to offer good services, so we can justify our price difference." (Collaborator - Portfolio Manager)

34) "we share APIs and in terms of really concrete data we share various vehicle data, because in our car industry, in our environment we have a lot of third party players in the market and us as an OEM" (Collaborator - Portfolio Manager)

35) "Now we need to offer good services, so we can justify our price difference." (Collaborator - Portfolio Manager)

A.4 Case Company Ecosystem Co-creators

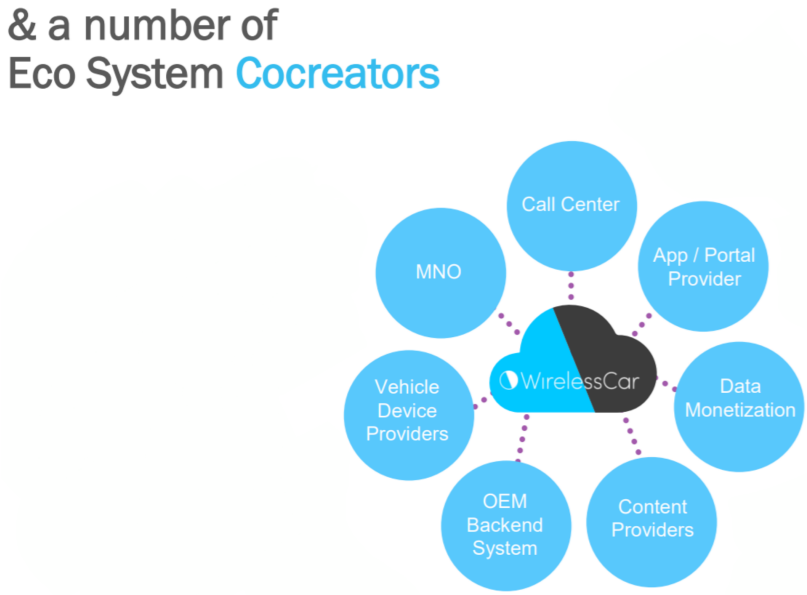

Figure A.1: (Anonymised) Case Company Model of Ecosystem Co-Creators

B

Appendix 2 - Iteration 2

B.1 Usability Study Survey Questions

Q1 What is your role in the company?
[single choice: Developer, Architect, Product Manager, Other]

Q2 Why did you select the modelling technique that you chose to work with?
[open-ended]

Q3 Does this modelling technique provide a good visual representation of the ecosystem?
[5-point scale (Strongly disagree - Strongly agree)]

Q4 What did you think of the modelling technique?
[5-point scale (Difficult to use - Very easy to use)]

Q5 If your model were to be presented to others within [your program], do you agree that they will understand this ecosystem?
[5-point scale (Strongly disagree - Strongly agree)]

Q6 Are there any elements in the model which do not assist in representing the ecosystem? If so, please specify.
[open-ended]

Q7 Are there any components which could be added to enhance the model and the representation of the ecosystem. If so, please give your recommendations.
[open-ended]

Q8 Do you think that ecosystem models could be relevant for future use cases in the company?
[5-point scale (Strongly disagree - Strongly agree)]

B.2 Usability Study Online Page

B.2.1 Introduction

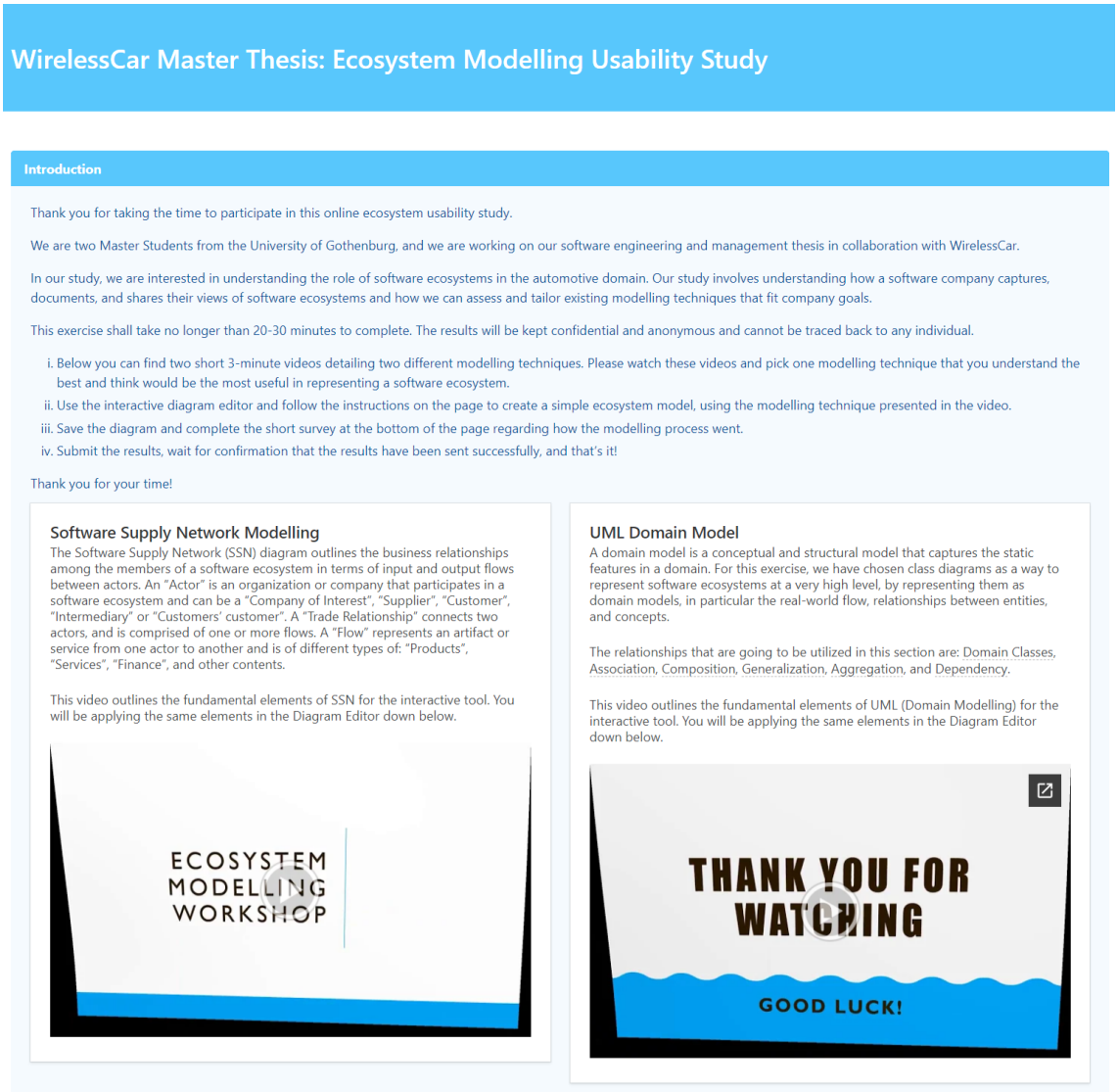

Figure B.1: Introduction section showing the description of the task and the videos presenting the modelling techniques

B.2.2 Modelling tool

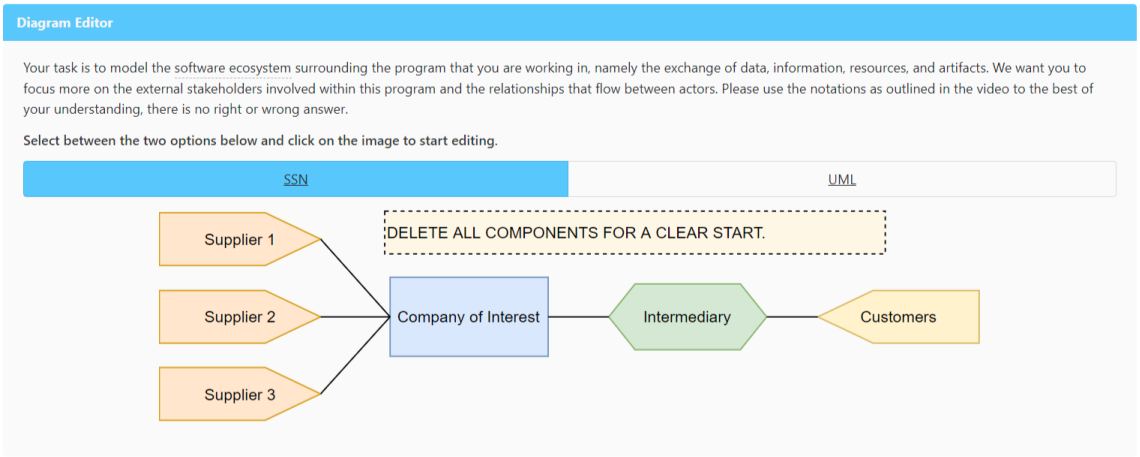

Figure B.2: User tasks and diagram editor section

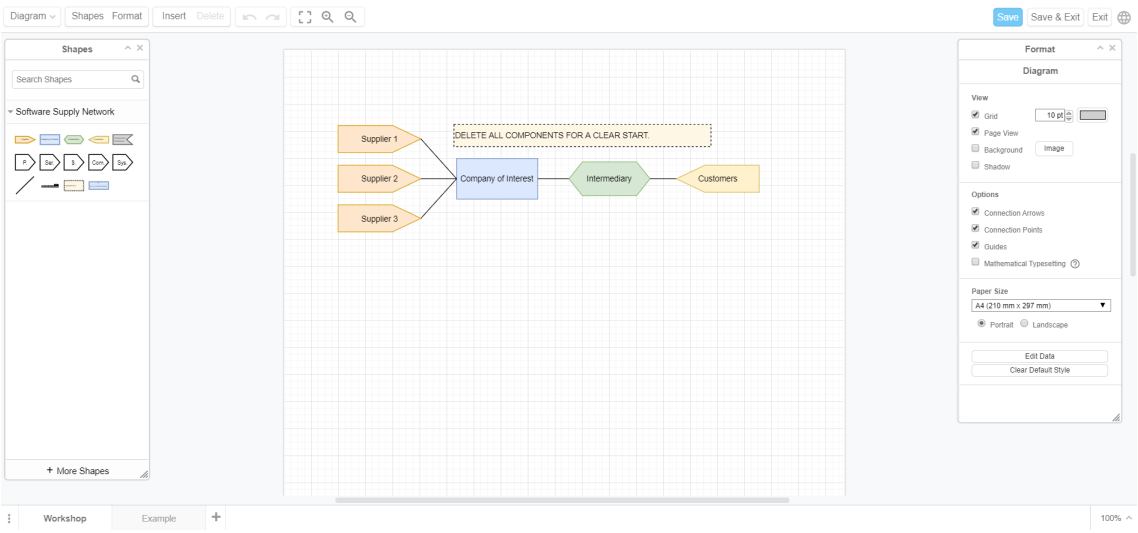

Figure B.3: Diagram editor modelling page

B.2.3 Survey

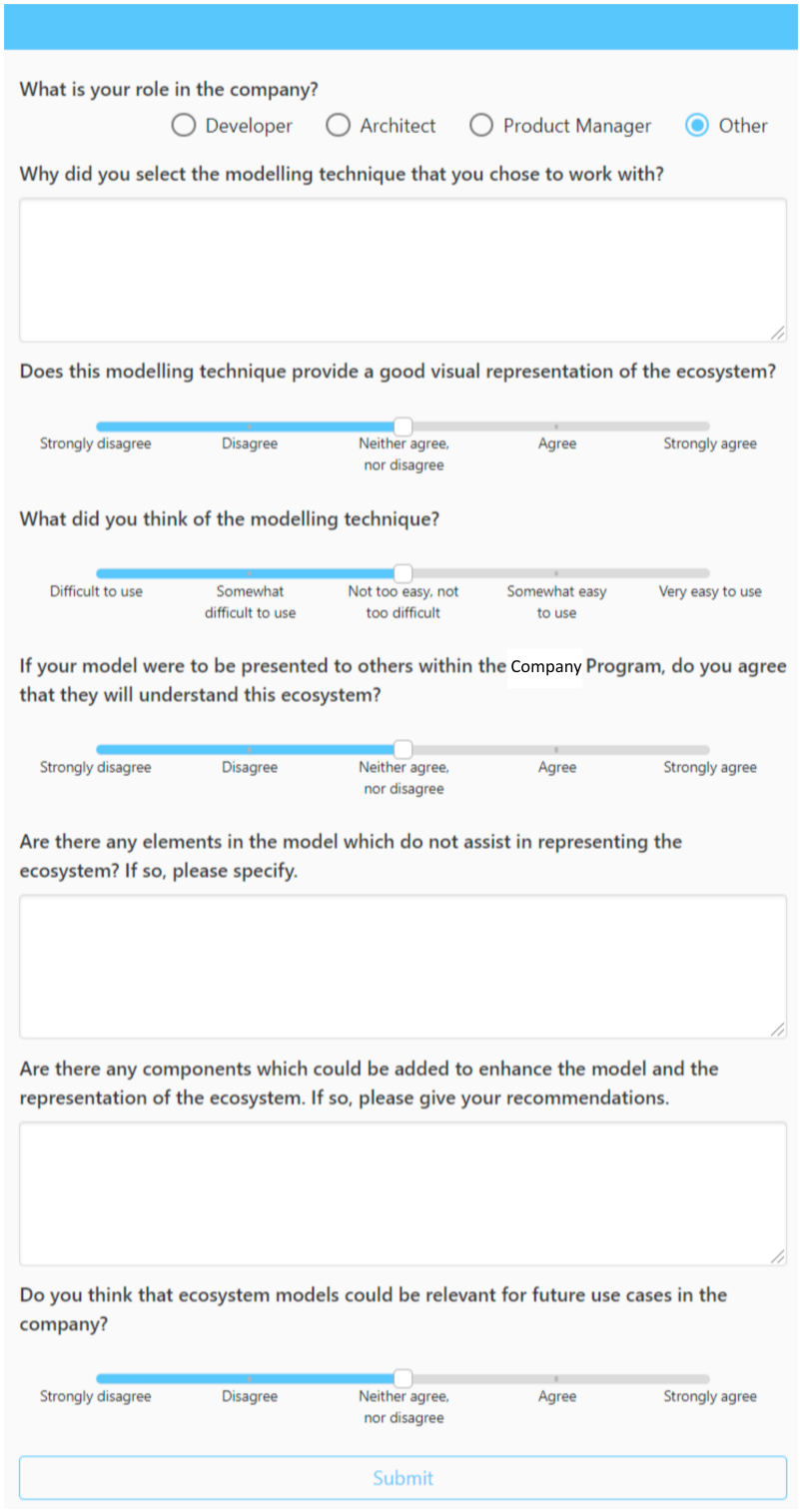

Figure B.4: Survey to be completed after the completion of the models

B.3 Usability Study Answers

B.3.1 Open-ended answers

Why did you select the modelling technique that you chose to work with?

a) "SSM seems better suited for the type of high-level business ecosystem modelling that was requested. UML seems better suited for more technical details, as concepts such as classes, composition, inheritance and so on have particular and very exact meanings in a technical situation – although possible to apply to any situation in theory, it automatically leads my thoughts into more of implementation details and less to the big picture of actors in an ecosystem."

b) "SSN brings more details to make a model which will be useful for stakeholders"

c) "Given the focus on external stakeholders and the need to represent financial exchanges and service offerings in-between, it was easier for me to visualise and represent the software ecosystem as an SSN model. For me, there is an inherent mental association between using UML and depicting a software down to it's smallest, represent-able details. This, also influenced the choice to avoid UML and use SSN when a high-level model needs creating."

d) "I have been familiar with UML from my education and thus find it much more comfortable and natural to work with."

e) "I know UML"

f) "Chose to work with SSN, it was easier to focus on external stakeholders and their involvement using this approach. Prefer to use UML when describing software in greater detail which was not required in this case thus, avoided it."

Are there any elements in the model which do not assist in representing the ecosystem? If so, please specify.

a) "The fact that many elements were identical or at least similar (the white boxes formed like arrows, representing different things such as 'software' and 'service') confused me. Were they supposed to be notably different? This is probably my main criticism of the modelling technique."

b) "No"

c) "Exchange of money could be excluded from the model, it is difficult to accurately represent without putting a wall of text besides. Component/ Services/ System differentiation may not be necessary since external stakeholders are almost never aware of these."

d) "Filling this answer solely because it has been marked as obligatory."

e) "No"

f) "Could do without the differentiation between Component, System and Services since it makes little difference to external stakeholders. Payment model

within [case company] is quite complex, difficult to give a representation for runtime fees and non-standard support costs using the elements available (probably unnecessary too)."

Are there any components which could be added to enhance the model and the representation of the ecosystem. If so, please give your recommendations.

a) "Lines did not default to have any direction, and although I more or less assumed a left-to-right data/value flow, perhaps somebody else would not have made the same assumption. Defaulting to directional arrows (allowing bidirectional in some cases) would perhaps be a good idea to enforce an understandable structure."

b) "No, the component for description gives the opportunity to clarify if something needs to"

c) "Nope, less is more in this case."

d) "There are different ways we get user stories/tasks. As it is in my model only one is shown. Many others are possible and one has to adapt, finding a way to make things happen. I don't think this necessary flexibility can easily be made into a tidy diagram that explains all possibilities."

e) "Can be more detailed. Depends on the main concern"

f) "-"

B.3.2 Usability Study Participant Models

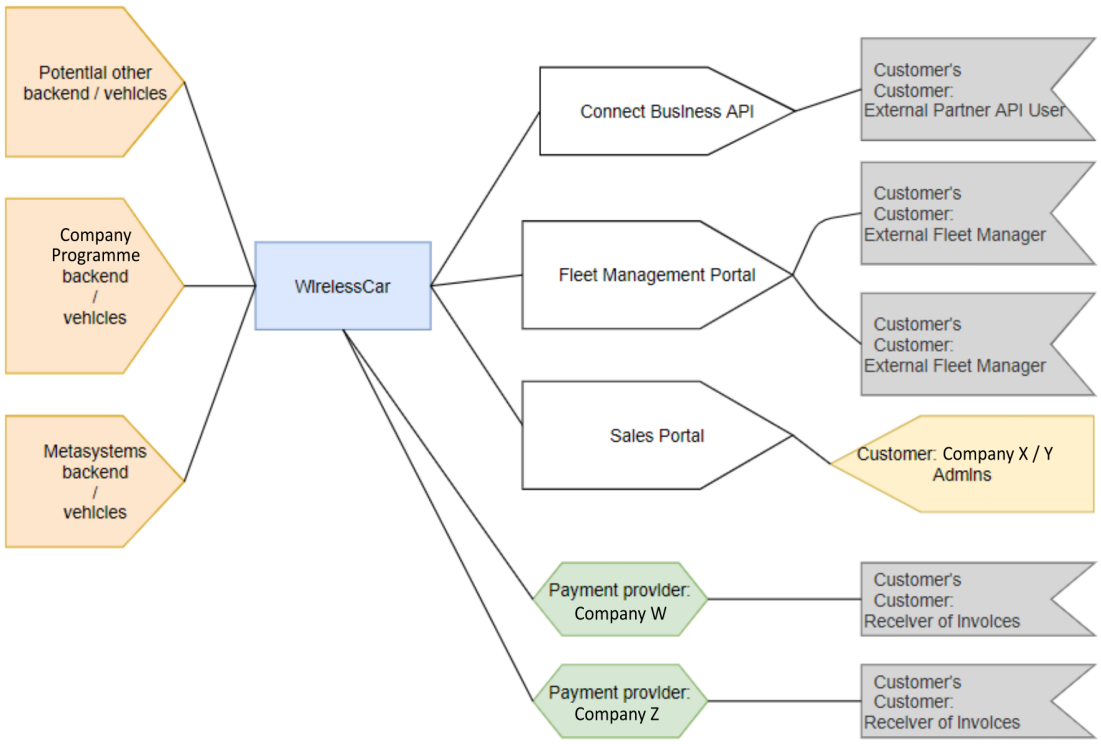

Figure B.5: SSN model created by a study participant

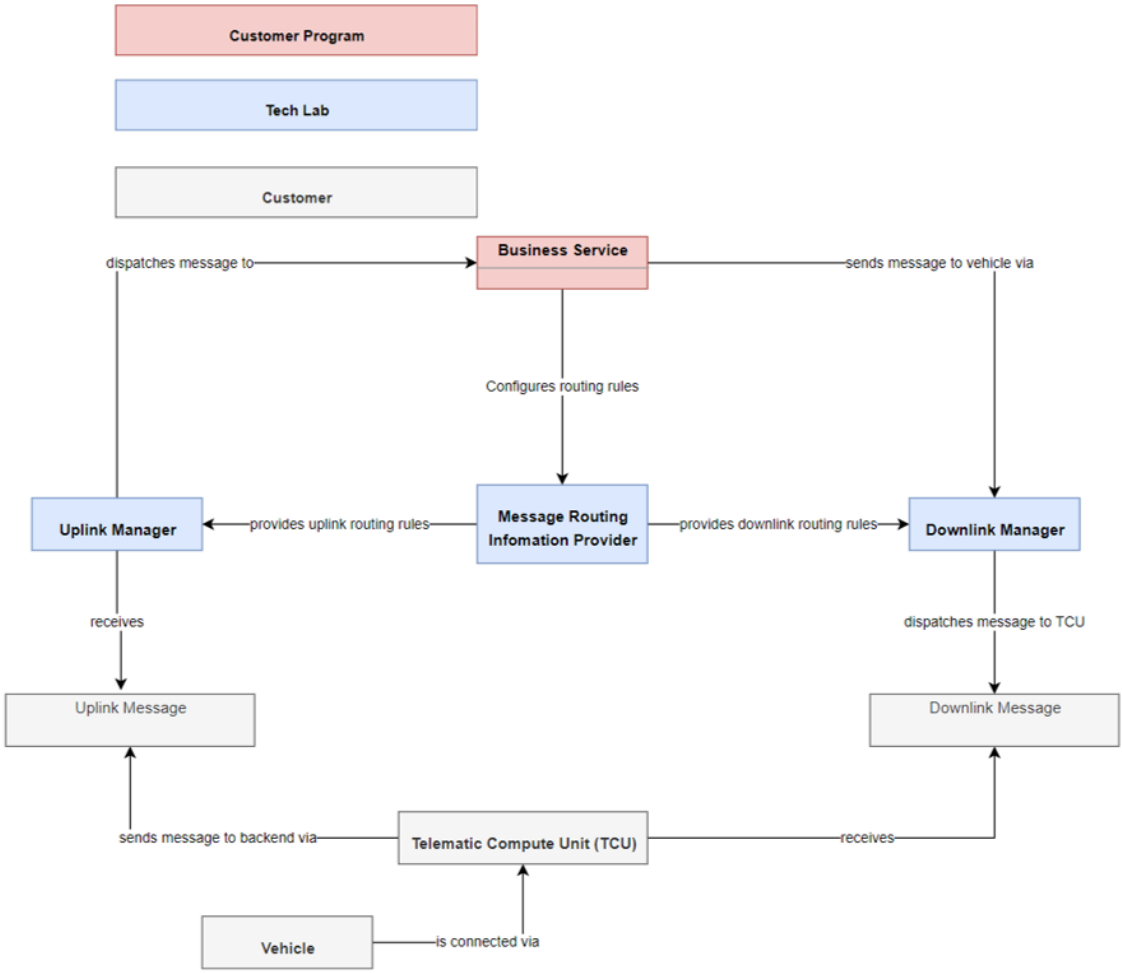

Figure B.6: UML model created by a study participant

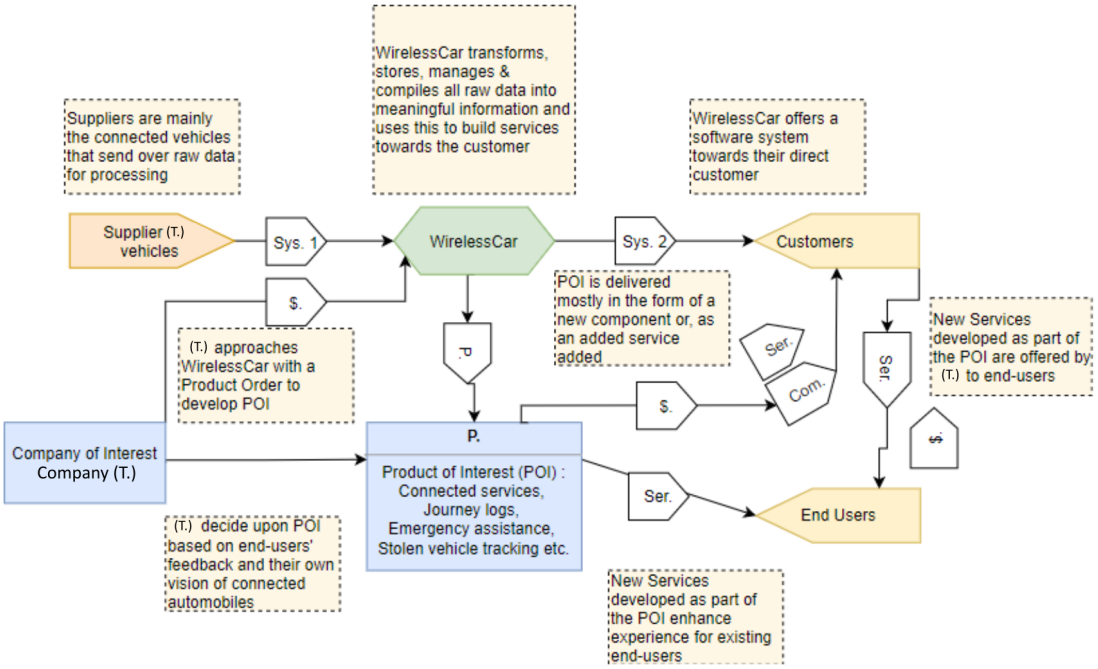

Figure B.7: SSN model created by a study participant

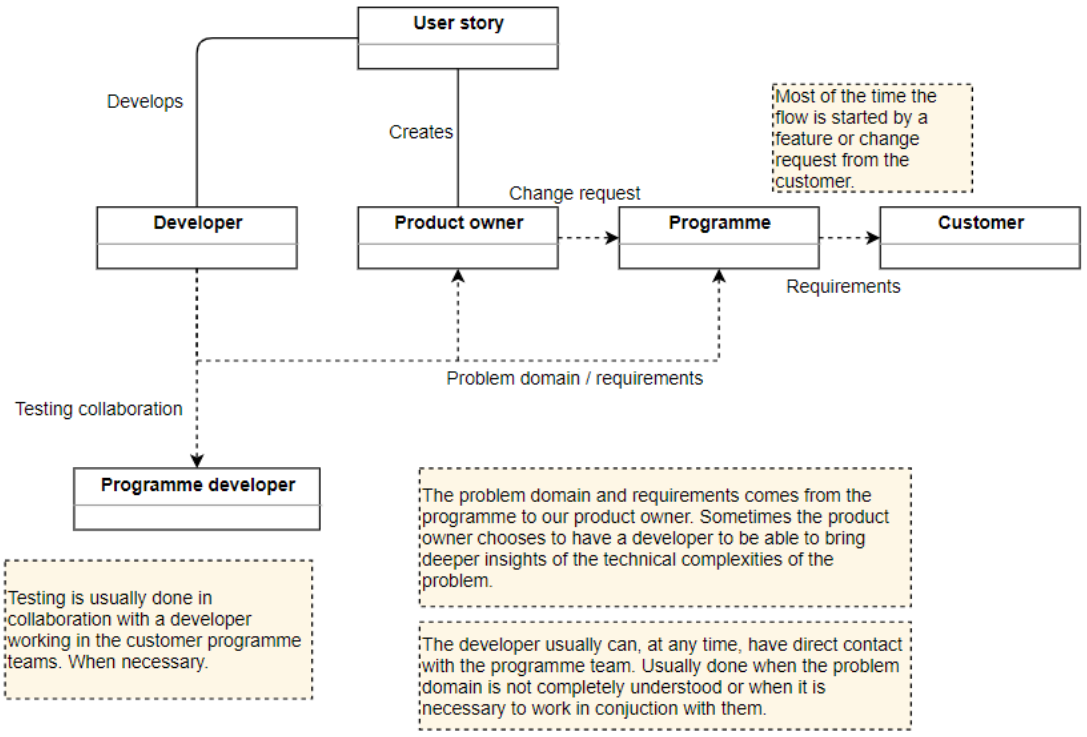

Figure B.8: UML model created by a study participant

C

Appendix 3 - Iteration 3

C.1 Modelling Technique Proposed Changes - Survey Questions

Change 1 Bi-directional arrows

Lines have been added in order to show directional flow and bi-directional flow. The trade-relationship flow: Software Component (Com.), System (Sys.), and Finance ($.) has been removed.

Q1 How would you assess this change to the model (bi-directional arrows)? [5-point scale (Not very useful - Very useful)]

Q2 Why do you think this change is useful/not useful for modelling ecosystems? [open-ended]

Change 2 (dependency arrow + components redesign)

Dependency arrows have been added to the model to visualize relationships where one actor depends or is an extension of another actor. Components have also been streamlined to avoid confusion regarding the direction in which they are pointing.

Q3 How would you assess this change to the model (dependency arrow)? [5-point scale (Not very useful - Very useful)]

Q3 Why do you think this change is useful/not useful for modelling ecosystems? [open-ended]

Change 3 (Icons)

Icons have been added to the actor components to help individuals in the modelling of the ecosystem and to help understand the ecosystem model.

Q5 How would you assess this change to the model (Icons)? [5-point scale (Not very useful - Very useful)]

Q5 Why do you think this change is useful/not useful for modelling ecosystems? [open-ended]

Assessment of all changes

Q7 Which of the presented changes would make the model better? (select all that apply)
[multiple choice: Change 1 (Bi-directional arrows), Change 2 (dependency arrow + components redesign), Change 3 (Icons)]

Q7 What other additions could be added to models to make them more useful for presenting ecosystems?
[open-ended]

Q7 Which of the three changes would bring the most value to ecosystem models?
[single-choice: Change 1 (Bi-directional arrows), Change 2 (dependency arrows + components redesign), Change 3 (Icons), None of the above]

Q7 In what ways could you see ecosystem models (in particular this modelling technique and changes) be used in the company? (pick all that apply)
[multiple choice]

- Documenting business partners & relationships
- Presenting information during meetings with stakeholders
- Used for onboarding new employees
- Sharing ecosystem knowledge across the company
- Creating consistent company guidelines and documentation
- Developing new business strategies and strategic partnerships
- Assisting the collaboration between programs and/or external stakeholders
- Understanding the impact of the automotive transformation process
- Visualizing ecosystem changes
- I dont believe these models will help the company at all

C.2 Modelling Technique Proposed Changes - Open-ended Answers

Change 1 Bi-directional arrows – Why do you think this change is useful/not useful for modelling ecosystems?

a) "Previous to this survey I have not been familiar with SSN. I therefore feel completely unqualified to give an assessment on the usefulness of this change."

b) "I think that the flow alternative is covering the most needed relationships and value streams. But the removal of Com, $ and system is generally good since they only confuses the picture."

c) “I think the change is useful because it will be clearer to follow the flow between entities”

d) “It will be a useful change, makes use of simpler elements (Service, Product only) which are understood by people in all roles. I did not think it necessary to utilise all the elements when using SSN though, thought it was only a suggestion (?)”

e) “The direction of ’service’ or ’product’ arrows already represent the direction of flow. Same product or service flowing in both direction is meaningless”

f) “Easier to understand flow that way then in original”

g) “Having arrows make it easier to see the direction of the so called "flow". It clears up in understanding the collaboration. ”

Change 2 (dependency arrow + components redesign) – Why do you think this change is useful/not useful for modelling ecosystems?

a) “Previous to this survey I have not been familiar with SSN. I therefore feel completely unqualified to give an assessment on the usefulness of this change.

However, if before we had a way to show bidirectional relationships I can assume that it was an useful modeling tool. I can see now that the bidirectional functionality is gone.”

b) “Would still keep the flow but to be able to show dependencies is a good add-on, as well as streamlining the components to avoid unwanted directional misconceptions.”

c) “Seems like a good idea to differentiate between dependencies and flows. The redesign of the components may be an issue for people with "color blindness" though since it relies only on different colors to describe the intent, you need to be clear with the text in that case.”

d) “Streamlining component representations is quite useful, avoids needless confusion about placing things a certain way. The change with the dependency arrows is not quite so useful in my opinion, especially if it’s done in favor of removing the "Comment Box". It may add considerable amount of text as part of the SSN representation and distract from the actual flow of exchanges.”

e) “SSM focuses on the flow of value between participants in the ecosystem. Not sure if dependencies are that relevant in this context. For instance, Uber employs its drivers in some countries, while in the rest they are independent contractors. Yet, both cases could be represented by the same SSN”

f) “Dependencies are important overall to highlight to make sure that high level picture is understandable and easier to implement, as it would be visible on what to start at”

g) “Dependencies may help to an extent. The previous arrows were more helpful as you can establish relationships such as dependencies as well if you can model that using other components. Dependencies would be good though as you can see what or who is dependent on others.”

Change 3 (Icons) – Why do you think this change is useful/not useful for modelling ecosystems?

a) “Previous to this survey I have not been familiar with SSN. I therefore feel completely unqualified to give an assessment on the usefulness of this change.

However; it does not feel that adding nice icons to the classes is at all useful when you lack all the tools (figures) to show relationships and flows.”

b) “Icons are generally good, but it is very important that the icon is easy to understand, might for example change the Company of interest icon since that is a location pointer :) But generally icons make the picture "more interesting" and easier to remember.”

c) “I think you would also need some sort of "generic" component in order to model things that does not fit into this structure.”

d) “Easier, more recognisable, very useful. Would be fine without if every element was a different colour but since that is not the case, icons would be quite useful.”

e) “I think icons do as good job as geometrical shapes”

f) “Answering this from value perspective - not sure if provides value to be honest, it’s nice to have, looks more modern look, but in the end I don’t feel that it provides extra explanation (again, imho)”

g) “I don’t think the icons would help so much as the other changes. It could also be confusing for some since it will add too much to the diagram. There are already so many components.”

Assessment of all changes – What other additions could be added to models to make them more useful for presenting ecosystems?

a) “I would say that the original models are fine and probably don’t need any changes, the challenge is having the competence to understand them across the company. As it is right now I don’t see any need to use a new modeling tool.”

b) “Possibility to show sequential relationships between different entities.”

c) “All additions above are useful, but as mentioned earlier "Change 3" is probably required if you want to do "Change 2". Also, an additional generic box for "Change 3" would probably be helpful.”

d) “Partially agree with "Change 2" i.e. streamlining of components.”

e) “SSN seems to be good as it is. Icons can make it more presentable. But that’s more of a taste thing”

f) “Grouping consumers - producers maybe”

g) “I like the first change the most, but you could make the boxes similar to that of the second change. It would be good to have another component that is marked "others". So people can add whatever they want to make the diagram” understandable.