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Designing a Requirements Elicitation Approach for Intelligent and Interactive Systems in Autonomous Vehicles

Master's thesis in Software Engineering programme

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Abstract

Software is becoming an increasingly large part in the automotive industry. From vehicles being connected to each other through networks to artificially intelligent algorithms that aid people while driving, software is quickly becoming an essential part of the vehicle and it will only keep growing as we steer into the age of autonomous driving. Because of this, a thorough requirements specification is needed in order to understand what drivers need from the intelligent systems in their vehicles, but also what system needs have to be fulfilled for the vehicles to reach its full potential. There is not enough research about how requirements can be elicited in the context of intelligent and interactive systems in autonomous vehicles. In addition, there is no proof that traditional requirements elicitation techniques work for these types of systems. The aim of this thesis is to investigate the issues and challenges of traditional requirements elicitation techniques in the context of intelligent and interactive systems in autonomous vehicles and based on the results, propose an approach for eliciting requirements. In order to achieve this, we performed three iterations using the Design Science Research (DSR) methodology. In each iteration, we started with discovering the problems that we are facing right now. Then, we produced an artifact that would address those issues and finally, we would evaluate our artifact. Using this approach helped us propose a requirements elicitation approach consisting of a process model for innovative concepts and a requirements elicitation tool.

Keywords: requirements, elicitation, autonomous vehicles, automotive, intelligent systems, interactive systems, context awareness.

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Contents

List of Figures

List of Tables

1

Introduction

During the past few years, the automotive industry has been significantly affected by the industrial software revolution. With the rapid growth of software in vehicles over the past 30 years, software has become an essential factor for the progress of the automotive industry [1]. More and more software-based innovations exist now with the purposes of enhancing the safety and comfort of passengers, and even saving lives [2]. The current trend in the automotive industry is to head towards implementing more artificially intelligent software in vehicles [3].

Since the inception of intelligent and interactive systems in vehicles, the driver is not alone anymore. Drivers are no longer the only ones making decisions in the vehicle. These systems are designed to assist them and to be co-drivers, in addition to making driving safer and more comfortable [4]. The increase in intelligent and interactive software development drives innovations in the automotive industry, but also leads to challenges caused by the nature of automotive systems which are highly complicated, safety related, and real time [5].

As the size and complexity of automotive software increases, software requirements gathering becomes an important step in the development of intelligent and interactive systems [6]. It ensures that different organizations have a shared understanding of the development goals which represent the correct needs of the customers. However, the limited knowledge about how to specify or even elicit requirements for these complicated systems is becoming an impediment for both development and user satisfaction [7].

More specifically, when speaking about the requirements of an intelligent system in autonomous vehicles, researchers and engineers tend to either focus on the functional requirements [8] or drivers' expectations or acceptance [9] of autonomous vehicles. There is a lack of empirical research or practices that combine both of these fields. This causes an issue because, in order to reach their full potential, autonomous vehicles must both deliver state-of-the-art technology and appropriate interaction in order to offer drivers the driving experience that they wish for.

1.1 Statement of the problem

A survey conducted by Wee et al. [10] shows an increase in people who are aiming to change their vehicles to ones that have more intelligent systems. Furthermore, 66% of drivers in a study conducted by Kristein [11] believe that the autonomous cars' technologies are smarter than the average drivers. Nevertheless, people are still worried about certain issues related mainly to the safety of drivers and vehicles, and mostly to a safer use of interactive systems in vehicles. Because of this, the need to build more intelligent systems which fulfill drivers' needs has increased [12].

Additionally, a study conducted by Reagan et al. [13], in which the authors observed drivers in order to check the interactivity level between them and autonomous systems, concluded that many drivers disable the warnings coming from the systems. The reasons behind that are that some drivers do not trust the systems because they are unreliable as they give information at the wrong time, or a big amount of information annoys them. Therefore, to build the right interactivity level in a system, and taking into consideration what drivers want and do not want becomes an important factor to save effort and money and keep the driver satisfied.

Requirements engineering plays an essential role in making the vehicle of the future a reality by developing the necessary technologies that deliver a fully autonomous driving system that meets customers' needs and expectations [14]. Companies now are looking for the right and convenient system engineering requirements for the customers to be developed and implemented into autonomous vehicle systems. Many recent studies and publications reflect autonomous vehicle implementations, but only few specify expectations of users' experience in autonomous vehicle systems [15]. Therefore, collecting requirements from customers for intelligent and interactive systems in the context of automotive systems is a challenge to system requirements engineers.

Braun et al. [16] report that inappropriate requirements engineering is one of the challenges of software engineering in the automotive industry. Requirements engineering significantly affects project success if done poorly [17]. We believe that adding more functionality is useless without the right list of requirements. By comparing the automotive industry domain to other domains, the cost of failure while the product is already in the market may be catastrophic [4]. Low trust and low experience in an automated system in vehicles will lead to under-usage, whereas overestimating a system's capability may lead to misuse and therefore possibly critical (or deadly) situations [4]. The essential point is to design a smart system in a way that drivers understand its possibilities as well as limitations. Thus, the focus on the drivers' needs and how they engage with their vehicles creates an exciting space to achieve the right system, level of interactivity, and decision making. Unfortunately, the increase in research on the benefits of user-centred design for intelligent and interactive systems development has not been matched by an increase in practical guidance and advice on how requirement engineers should conduct this work. Choosing the right elicitation techniques for a project is one of the biggest challenges that they face.

1.2 Why new approach?

"Once a requirement gathering technique that does not fit the current project is selected, the project will proceed along the road to failure." [18]. Un-captured errors and bugs in the early stages of the development process are the hardest to fix later on [19]. The effectiveness of a chosen elicitation technique is crucial [20]. As it refers to the ability of the technique to produce the right requirements that are needed to make the project successful. Effectiveness has been evaluated using a quantitative approach in previous research such as [21] [22]. This quantitative approach determines effectiveness without taking into account the project as a whole, but instead views techniques in isolation of the project context [20]. With the invention of new interaction mediums between the user and the application, the context in which the application is being used becomes an essential part of the activity carried out with the system [23]. It also becomes an important factor when deciding the elicitation techniques' effectiveness. *"The notion of context should be extended to different categories: computing contexts, user contexts, and physical contexts"* [23]. Therefore, the traditional human-computer interfaces theories are not adequate for implementing context-aware applications anymore. This leads to a demand for a new form of system requirements elicitation and design which makes good use of this extended context notion.

Additionally, involving real users while eliciting requirements is a vital part in collecting high quality requirements. Generally, the analytic methods gather the requirements from different sources, rather than the customers or the end users. Other requirement elicitation techniques cause a major problem in not fulfilling the expectations of the users, in case the right users are not chosen [24].

The two main motivations for designing a new requirement elicitation tool in this project are: helping the requirements engineers to take the context of the system into consideration, and involving the end users in evaluating the systems and collecting their real needs.

1.3 Purpose of the study

The purpose of this study is to help requirement engineers get a list of user requirements for the intelligent and interactive systems for autonomous vehicles. This list should encompass a foundation for designing the right system with the right features. This has been achieved by looking at the issues that requirements engineers currently face in the automotive industry and developing a new approach to elicit requirements for such systems. The following aims were targeted during the thesis:

- Collecting and specifying requirements elicitation problems in the context of intelligent and interactive systems in the automotive industry.
- Study potential solutions for the proposed problems.
- Validate the effectiveness of the reported solutions that have been explored in the previous point.
- Provide the company with a list of requirements and feedback regarding the intelligent and interactive system that they are currently working with.

1.4 Research questions

In this thesis, we aim to answer the following research questions:

RQ1: What are the problems of requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

RQ2: What are potential solutions to conduct requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

RQ3: To what extent can potential solutions address the problems of requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

In RQ1, we will find problems and challenges in eliciting requirements through the experience of requirements engineers and researchers at Autoliv.

In RQ2, we will mainly analyze and study requirement elicitation (RE) challenges that were discovered by interviewing researchers and engineers at the company and use the analysis to create solutions for these problems.

RQ3 will assess the feasibility of using the approach which is built in RQ2 to answer whether this technique can be employed to solve those problems and to what extent. The approach will be used to provide the company with a list of requirements related to the LIV research platform.

2

Review of literature

We covered four main areas during our literature review, i.e. Challenges in Requirements Engineering, Requirements Elicitation Techniques, User Involvement, and Processes for Innovation Projects.

Initially, we started with looking for challenges and issues in requirement elicitation within the context of the automotive industry from previous studies. However, we discovered that there is very little known about that area, so we decided to look at literature that covers these issues in traditional projects and use the papers that we found as a starting point for our thesis. We also included work focusing on the importance of combining elicitation techniques in order to come up with a more complete requirements specification and avoid ambiguity in requirements.

Then we aimed to study different types of requirements and their elicitation techniques. That makes a ground for us in how to choose the right list of elicitation techniques for systems in the automotive industry. We cover multiple types of requirements elicitation: Contextual Requirements Elicitation focuses on methods that can be used in order to elicit requirements while taking into consideration the context in which a system would be used e.g. weather conditions, the interior of a car, the type of work that users must perform when using the system, etc. Real-time requirements focus on the need to extract requirements in real time and trace them back to the stakeholders that came up with them.

We also include a discussion of the Importance of User Involvement. We cover Personas and present a data-driven tool that generates them based on user research. We have included Personas because we believe that personas could help improving the process by involving more users of the system and covering different groups of users.

Finally, we present a model for developing innovative projects. As LIV is an innovative concept, we intend to come up with a process that helps Veoneer develop this while at the same time involving users.

2.1 Requirement engineering challenges in the automotive industry

2.1.1 Requirement engineering demands for product service systems

Berkovich et al. [25] conducted an empirical study aiming to explore experiences and gain knowledge regarding requirements engineering of product service systems (a combination of product, software and service elements) in the automotive industry. The study was carried out by conducting 15 interviews with interviewees who had different areas of expertise and roles. As a result, Berkovich et al. state many demands to be included in such systems. One of the demands is a stronger involvement of the customer into the requirement engineering process. One of the other main demands that the authors mention is to be careful in the selection process of stakeholders. Selecting the right stakeholders is a very important aspect when gathering requirements. The authors agree that the selection of stakeholders which are not relevant for the system or a wrong selection of stakeholders can have a negative effect on the products. In our project, one of our aims is to discover the challenges that requirements engineers face when eliciting requirements for interactive and intelligent systems in the automotive domain and Berkovich et al.'s paper provides us with a good starting point.

2.1.2 Combining requirement elicitation techniques

Jiang et al. [26] performed research into the selection and combination of RE techniques as well as a case study that applied the selection process to an industrial software project in a company. As a result, the company was able to develop a much better requirements specification, with more accurate requirements, a clear structure, and traceability of the requirements. The most important achievement was that the ambiguity and conflict in the requirements were greatly reduced. Mishra et al. [27], in their paper, presented an application that combined requirements engineering techniques for a real life complex project. They reached the same results as Jiang et al. [26]. We can learn from their results that a combination of requirements elicitation techniques can effectively be used to elicit, verify, and validate requirements for complex software development projects. This will give us a good idea to think about while we are designing a new elicitation technique approach for the system we have.

2.2 Requirements and their elicitation techniques

2.2.1 Contextual requirements

Contextual Requirements Elicitation

Keller et al. [28] presented the "Contextual Inquiry" method for contextual requirements elicitation for software systems. Contextual Inquiry is part of a larger design process called Contextual Design. Mainly, Contextual Inquiry is a field interviewing method. It seeks to understand the customers and their work. Contextual Inquiry is based on four principles which are Context, Partnership, Interpretation and Focus. The principle of context demands that the requirements engineer goes to the customer's workplace and observes the work conducted there. Partnership is when the requirements engineer and the customer collaborate equally in understanding the customer's work. Interpretation requires that the data resulting from the observation be analyzed and interpreted. Finally, the principle of Focus states that the interviewer needs to have a focus to see more of the work. Contextual Inquiry gives the requirements engineer detailed instructions on how to lead an interview. The approach the authors mentioned is pragmatic and easy to understand, but a major disadvantage is that the combination with other eliciting techniques is not discussed. We believe that this paper will help us in understanding how we can create a contextual elicitation technique.

How to select the right elicitation techniques for Contextual Requirements

In a case study conducted by Knauss et al. [29], the authors provide a useful guideline about which requirements elicitation techniques could be used when eliciting contextual requirements. When eliciting contextual requirements, requirements engineers must not just take the system into consideration, but also the environment in which the system is used. The goal of the case study [29] was to analyze how useful existing requirements elicitation techniques are for the identification of contextual requirements early, i.e. at design time. The elicitation methods that were treated in this study were interviews, prototypes, scenarios, goal-based approaches, and focus groups. The authors worked in collaboration with the Human Resources department at the University of Victoria in revising its job applicant tracking system. First, they identified requirements through interviews and focus groups, then conducted more focus groups in order to comprehend the motivation behind the identified requirements. Then they created prototypes in order to understand the identified requirements in context. Finally, they identified conflicting requirements between different end-users when they discussed them together in detail in focus groups. The authors gathered valuable insights during their research:

1. Conflicts between different stakeholders' requirements indicate the need for contextual requirements.

2. Different points of view are valuable in order to identify the context related to requirements and to analyze contextual requirements.
3. Prototypes are particularly helpful to understand the context of conflicting requirements in detail.
4. One requirements elicitation method is not enough. They have to be combined because they each have different purposes.

This paper will give us guidelines to follow when choosing the right list of elicitation techniques in the context of automotive industry.

New requirement elicitation techniques for context aware applications

Hong et al. [23] extended the notion of the context to three different categories: computing contexts (the hardware configuration used), user contexts (represents the human factors), and physical contexts (non-computing-related information). Based on the importance of the context in reducing the input cost, increasing the communication's efficiency between humans and computing devices, and providing an exciting user experience, the authors used the concept of extended context as a foundation of requirements elicitation for ubiquitous application design to present a meta-model and methodology for this purpose. To create the meta-model, the authors considered two goals, the usability goal, and user experience goals. The methodology that they proposed is as follows:

1. Figure out the target user groups.
2. Estimate the contexts that suit each user group.
3. Gather the requirements specific for each context defined in the previous step.
4. Define the users' actions while using the system.
5. Define the required context-aware features.
6. For each context-aware feature, specify the context aware capabilities.
7. The context-aware capabilities should match and satisfy all the requirements elicited previously.

We believe that this paper is useful for our study as it gives us basic ideas and extended notion of the context to start with while proposing our elicitation approach for interactive and intelligent systems in the automotive context.

2.2.2 Real-time Requirements

One of the great challenges of software engineering is to elicit complete and correct requirements [30]. Often during requirements elicitation meetings, a requirement engineer is present to take notes based on which requirements will be created later on during the process. This method has several drawbacks, the most important ones being that the requirements engineer could misunderstand what a stakeholder has said, that they might miss important stakeholder statements, or that they might take those statements out of context. To mitigate this issue, Gall et al. propose a new framework which aims to automatically extract important stakeholder statements in real time [30]. Requirements elicitation meetings are video recorded and stakeholder requests that constitute a requirement are automatically extracted as clips to a database along with a link that points to the meeting where the statement occurred [30]. These clips can be later used for extracting requirements [30]. This study provides us with the foundation for a tool that would both allow the extraction of requirements in real time and bridge the gap between users and system developers.

2.3 Importance of User Involvement

2.3.1 User Involvement

Gould and Lewis [31] outline three principles that they believe must be followed in order to build useful, easy to learn and use, and pleasant systems. These principles are:

- *"Early focus on users and tasks"* - the authors argue that design should be user driven, and that it is not enough to identify users. Instead, designers must understand them and the tasks that they have to perform.
- *"Empirical measurement"* - users should use simulations and prototypes of the system to accomplish their tasks. Their reactions, performance, and feedback should be recorded in order to measure learnability and usability. In addition, these studies should be conducted early in the process.
- *"Iterative design"* - issues discovered during user testing have to be fixed, ergo design must be iterative.

The authors argue that even though these principles might seem obvious once people hear about them, at the time they did not seem to be followed in practice [31]. One major reason for this was the fact that the value of interaction with users was miscounted. One of the reasons given for not involving users is that *"users do not know what they want"*. This statement is often thrown around in the context of innovation projects as well. However, the authors suggest that this problem can be mitigated by e.g. providing detailed scenarios, user manuals, or detailed prototypes of the system. At the time when this paper was written (1985), users had difficulty using and learning computer systems and the authors believed that following the three principles stated above would lead to more usable systems. We believe that these principles should be followed in the automotive industry as well, as it is facing the same issues that the computer industry faced 30 years ago.

2.3.2 Personas

Personas is a technique coined by Alan Cooper [32]. A persona is a depiction of an individual who represents a group of the targeted audience with certain traits and goals that they wish to accomplish. According to Cooper, personas are not fictional and should be derived from previous research [32]. The purpose of personas is to help researchers understand the behaviours and goals of the users of a system [32]. McGinn and Kotamraju came up with a data-driven persona-development tool [33].

Their method consisted of sending surverys, which contained questions regarding the most relevant information that the internal client that collaborated with the authors needed about the users. After gathering the responses from the surveys, they performed quantitative and qualitative data analysis on the gathered data [33]. Finally, they combined the analysis results into eleven different personas. We want to create an automated solution for the definition of these personas that helps our collaborators gain a better understanding of their audience and we believe that McGinn and Kotamraju's method is a good starting point for us.

2.4 Business model innovations

Trimi et al. [34], in their paper, linked the companies needs with the advantages of having a flexible and well-designed business model. They focused on a model which helps in reducing the risks that arise from making a large amount of investment for new concepts. The authors introduced the notion of the Minimal Viable Product (MVP) which was coined by Eric Ries [35]. The MVP is a prototype that implements only the most necessary features of the product to test and experiment the hypotheses which become viable to the customer to get the customer feedback in very early stages. MVP allows entrepreneurs to focus more on knowing who their customers are, and in updating and including them before it's too late. The model is based on Lean thinking, and it is shortly: *"build-measure-learn"* [35] feedback loop, an alternative to making a lot of hypotheses and assumptions. This can be summarized as:

Ideas → **Build** → Product → **measure** → Data → **learn** → Ideas (circle)

This paper is very useful for us, as we believe that parts of the MVP model can also be applied to innovation projects.

3
LIV

In this chapter, we introduce LIV (Learning Intelligent Vehicle), the research platform that we use to conduct this thesis. We also introduce important functionalities of LIV that we depend on in the thesis.

3.1 Case Company

We started our study in Autoliv which is a Swedish company and the world leading automotive safety supplier. Its main area of expertise is the development and marketing of safety devices in vehicles, such as airbags, seat-belts, steering wheels, passive safety electronics, and active safety systems. The electronics offering has been significantly strengthened to be well positioned for success in the market. Then, the strategy of Autoliv was to build two companies focused on and dedicated to their respective markets, so the newly-founded company Veoneer span off. Thus, Autoliv became responsible for the passive safety side, which makes products such as airbags and seat-belts whereas Veoneer is responsible for the active safety systems which offer driver assist systems, positioning, night vision, brake systems and advanced driver assistance systems (ADAS). Veoneer aims to be a leading system supplier for ADAS and autonomous driving [36].

This thesis project is conducted in collaboration with the research department in Autoliv (prior to the spin-off) and later on the resesearch department in Veoneer (after the spin-off). One of the most important responsibilities of Veoneeris to innovate and develop concepts whose aim is to establish trust between a vehicle and the driver in order to offer a great user experience, but also to decrease the number of car accidents and fatalities [37]. Currently, Veoneer Research is developing LIV, a concept whose purpose is to respond to context and establish trust both from the vehicle to the driver and from the driver to the vehicle. More details about LIV are presented in details in the below section.

3.2 LIV

LIV is an innovative concept that was previously developed by Autoliv Research and is now developed by Veoneer Research. Its development started out of a need to establish better communication and trust between the driver and the vehicle, since research suggests that drivers choose to disable various active vehicle automation services (e.g. AEB, ESC, and so on) because systems are unreliable, provide feedback at the wrong time and are annoying the driver [13]. It is a research platform that aims to demonstrate the company's vision of a safer future, which incorporates intelligent and contextual safety, where integrated systems act as companions which are aware of the drivers' habits and intentions, the surrounding environment, and data from the vehicle to increase safety. A future where the vehicle understands and responds to context, and in addition keeps the driver in the loop by allowing shared control between the driver and the vehicle.

3.3 The idea behind LIV

Veoneer (and formerly Autoliv) believe, based on previous research, that collaboration between vehicle and driver is crucial for system usage [38] [39]. Thus, the company's focus is to pave the way for shared control between driver and vehicle. In order to have shared control, two-way trust must be established both from the vehicle to the driver and from the driver to the vehicle. To achieve trust, both driver and vehicle have to be aware of each other's state and responsibilities, and this can only be achieved through communication.

LIV is created as an answer to the issue of "human error". Instead of taking all of the control away from the drivers, understanding them and their capabilities is essential to ensuring driving safety. The company's belief is that in order to achieve safe automation, a shared control should be allowed between driver and vehicle. By having shared control, issues such as loss of skill are avoided, since the driver still has to take over for part of the journey.

To achieve true shared control, i.e. a secure separation and delegation of tasks between driver and vehicle, each one has to be aware (in real-time) of what the other can and cannot perceive. For this, we need both intelligence and learning. It has been traditionally up to the driver to learn about the vehicle's system limitations, functionality, and use cases, and adapt to this new knowledge [40]. The cars include an increased amount of features and the driver cannot keep up with getting familiar with them and using them in a proper way. Hence, LIV is designed to support the driver in this as well, where LIV understands that the driver has difficulties in using the system and can support the driver. LIV also uses artificial intelligence to learn about the driver as the rise of capabilities in artificial intelligence now allows automation to learn about the drivers' limitations, skills, habits, and preferences. This way, the car can learn about the drivers' skills and capabilities, but this is still not enough to achieve shared control. Communication between the driver and the vehicle is necessary in order to understand the appropriateness of certain actions in a given context and to establish knowledge about what the driver and the system know. Without communication about the goals between driver and vehicle, cooperation cannot be achieved.

3.4 LIV functionalities

Table 3.1 shows some of LIV's functionalities which we are interested in while we are collecting the requirements and feedback from users.

Function	Function description
Emotion camera and Face ID	Identifies the driver and classifies driver facial expressions during the drive.
Active seat belts with microphones	Identify who is speaking in the vehicle using the seat belt microphones.
Driver monitoring system (DMS)	IR camera. Monitor where the driver is looking.
Seat, mirror and steering movement control	This is linked to the Drive ID. When the vehicle recognize the driver seat and mirror positions will be adjusted.
Dialog	Possible for vehicle occupant to communicate by using seat belt mic.
Night vision (NV) system with dynamic spotlights	Night vision system embedded in the UI.
zForce steering wheel	Hand-on detection (HOD), Light feedback, Gesture detection, Touch switches.
Display control	Using HDMI displays which give system more freedom to show anything in the displays and does not interfere with the original display.
V2X	Cloud based V2X.
GPS with RTK (real time kiwetic)	Needed for path following. Provides the opportunity to test and display various handover situations.
Roof light	Possible to visualize object and track object with 360° roof light RGB´s.

Table 3.1: LIV's functionalities, which have been used for gathering requirements and feedback during this thesis.

3.5 Why we are using LIV

LIV, as an intelligent and interactive system in the vehicle needs to be validated and checked to which extent the interactivity and communications are acceptable by the drivers. Veoneer, additionally, is aiming to provide the drivers with the most effective system to fit their needs, so the company is interested to know users' feedback on the LIV research platform and to get all additional requirements the drivers would like to be implemented in the system.

In addition, we decided to use LIV for our research study because it is the type of system that we are aiming to find a requirements elicitation approach for. LIV is also a helpful tool in answering our research questions because:

a. By investigating how researchers and engineers came up with the requirements for this research platform, we can answer our first research question.
b. Based on the challenges that we discover, we can propose an approach to tackle them, which would provide an answer to the second research question.
c. Since the LIV research platform is still in the early stages of development, we will have the opportunity to evaluate it and see how and if it helps, thus providing answers to our third research question.

4

Research Methodology

We chose the Design Science Research (DSR) methodology in this thesis to answer our research questions. We followed the DSR cycle model described by Vaishnavi and Kuechler [41], which is explained in details in Section 4.2. The reason why we chose DSR is that the overall purpose of this methodology meets the requirements of our thesis' goal. Henver et al. [42] illustrate that the research in information systems is considered as a DSR model if it targets converting a social or organizational situation into a more appropriate one by using innovative artifacts. Since the aim of our research was to find a novel approach which would address the elicitation issues that requirements engineers are facing in automotive systems, we believe that DSR was the most suitable model to follow during this thesis. Additionally, a DSR project addresses a solution for a real-word problem [43]. We were outgoing from a real-world problem, which we built our awareness about by reviewing literature to build an artifact to be used in industry. We also wanted to close the gap between the artifact and its applicability in industry in an iterative way. Therefore, DSR was very suitable method to be used during this study.

Additionally, we used various methods that helped us in collecting data which supported us in getting the needed information and knowledge to find solutions and to evaluate these solutions. The data collection methods used are explained in Section 4.1.

Throughout the thesis, we will be using the terms "users","end users", "participants", or "drivers" to refer to the people that will eventually be users of the LIV system or the people who have tested it.

4.1 Data Collection Methods

4.1.1 Interviews

During this thesis project, we conducted face-to-face, structured interviews. This data gathering method was chosen because we wanted to gain a deep understanding of how researchers or requirements engineers at the case company elicit requirements. We also wanted to encourage the participants to give answers freely instead of choosing from a set of possible answers. Furthermore, we aimed for face-to-face interviews because we wanted to explain any unclear questions and clarify the terms we used. Each participant was interviewed separately to avoid potential bias caused by participants influencing each other.

A set of rules were followed when creating the interview questions [44]:

a. Leading questions, i.e. questions that imply an answer from participants, were avoided.
b. The interviewers remained as neutral as possible throughout the interview, i.e. they did not attempt to introduce their personal opinions or beliefs about the topics covered in the interview.
c. The questions were non-judgmental, i.e. they were posed in such a way that the participants understood that there was no specific or wrong answer.
d. Each question targeted a single topic in order to avoid ambiguity.
e. The participants could give any answer instead of choosing from a predetermined set. This was due to the nature of the interview and the fact that, especially as far as elicitation techniques were concerned, their answer might not have been included in the set.
f. Binary, i.e. "yes/no" questions were avoided.

The interviews were structured, which means that they followed a script of questions which were posed to all participants. This type of interview was decided upon because the data gathered from it would be easier to analyze than the data that would have resulted from an open-ended interview [45]. In addition, keeping to a script helped us ensure that the answers that we would receive from the participants would be consistent and thus we would not miss any of the important questions. Finally, structured interviews are easier to control from a temporal perspective [45] than open-ended interviews, which are very useful given the time constraints of both us and the participants.

After the questions were composed, a pilot test was performed. The aim of this test was to get an estimation of how long the interviews would take, and check if there were any questions that had to be modified, rephrased, or if there were any important questions that we had not thought of [46].

After conducting the interviews, we created the transcription for each interview, and sent it back to the interviewee. Each interviewee validated his/her transcription. All the comments and the changes they suggested had been accepted from our side.

4.1.2 Questionnaires

The questionnaire aims to gather self-report data about users' opinions, behaviours, or attitudes [45]. There are various ways to conduct questionnaires. During this thesis, we conducted paper-based questionnaires.

The questionnaires we used were semi-structured questionnaires which contained mixed type of questions, i.e. closed and open ones. Formulating the questions depended on the type of responses we wanted to get, i.e. open-ended questions were suitable when we wanted deeper insight - in other words, qualitative data - into certain subjects, while close ended questions were appropriate when we wanted to numerically analyze the results, i.e. quantitative data [45].

According to Roger [47], we kept the following four aspects in mind when we were structuring the questionnaires:

a. Consider in what order the questions should be asked, since this might determine the impact of each question.
b. Consider the people that our questionnaire is directed to, because we might need to make different versions of the questionnaire according to the population that the questionnaire is directed towards.
c. Give thorough instructions on how each question in the questionnaire should be answered.
d. Don't ask biased questions. For example, the question "How good is the system?" is not a good question because you are implying that all your respondents like the system.

4.1.3 Observation

During our research, we had the opportunity to evaluate the LIV research platform and our proposed tool with end users.

To do that, we used observation methods. Observation methods are used when you want to watch how and what people do. There are various different ways to do that. We used the naturalistic observation (i.e. unstructured observation) during our study [48]. It studies the spontaneous behavior of the participants in a natural context.

During the observation process, we investigated the participants' expressions and behaviour while trying the system features. We stored our data using video and audio recording, and notes, for further analysis.

4.1.4 Data Analysis

There are various tools to analyze qualitative data. However, according to Patton et al. [49], there is no perfect designed study to do the analysis. The basic motivation to do so is how much effort and time resources the researcher has to understand and accomplish the phenomena under study.

To analyze the interviews in our thesis, we used content analysis. Content analysis was performed in order to identify patterns in the interview participants' answers and to uncover the most important themes that emerged during the interviews [45].

For small data sets, the analysis could be done in a spreadsheet. If the data set is very large, there are software tools that are aimed to help researchers find common patterns and categorize the mentioned patterns. We used spreadsheets to accomplish the content analysis in this thesis.

As Hanington et al. [45] suggest, for each observation or insight, we decided on a few keywords that summarize what it was about or what category it belonged in. Afterwards, we grouped all keywords that addressed a common issue together in a category. For each subset of keywords, a theme with a meaningful name should be assigned. This last step should be iterated over until all themes were condensed into the most necessary and relevant ones, i.e. no two themes should be related in any way when the iteration part is over. All observations were extracted from the collected data and inserted into a spreadsheet. Every data item was then assigned a main theme and possible sub themes. Afterwards, the data was analyzed according to these themes.

4.2 Design Science Research

DSR is a problem-solving model. It extends the boundaries of a problem by creating and evaluating new artifacts to achieve understanding of the problem domain [50]. The concept of the artifacts is essential in DSR. The artifacts could be in the form of *"constructs, models, methods, and instantiations"* [51]. DSR works in an iterative way. A deeper knowledge about the problem is gained within each iteration, and based on this gained knowledge, in each iteration, the artifact is built or improved. The final artifact of each iteration is presented to technology-oriented and management-oriented stakeholders to be evaluated [52].

4.3 DSR Iterations

Generally, our research is carried out in three iterative cycles, following the cycle model proposed by Vaishnavi and Kuechler [41]. Each of the three cycles was conducted using the five-step process proposed by Vaishnavi and Kuechler [41], which consists of: awareness of the problem, suggestion, development, evaluation and conclusion. The five-step process is depicted in Figure 4.1.

Each iteration starts with investigating the problem to create awareness around it. Then based on the awareness knowledge gained, solutions are suggested. Then, based on the discussed solutions, an artifact is built and evaluated, during the development and evaluation stages. The final step in the iteration, the conclusion, indicates the end of the iteration or the project.

4.3.1 Awareness of the problem

In the beginning, we built our awareness of the problem through literature reviews of studies related to challenges and issues in requirement elicitation in automotive systems. Later on, we gathered data about requirements elicitation techniques and the issues related to them through conducting interviews. During the creation of

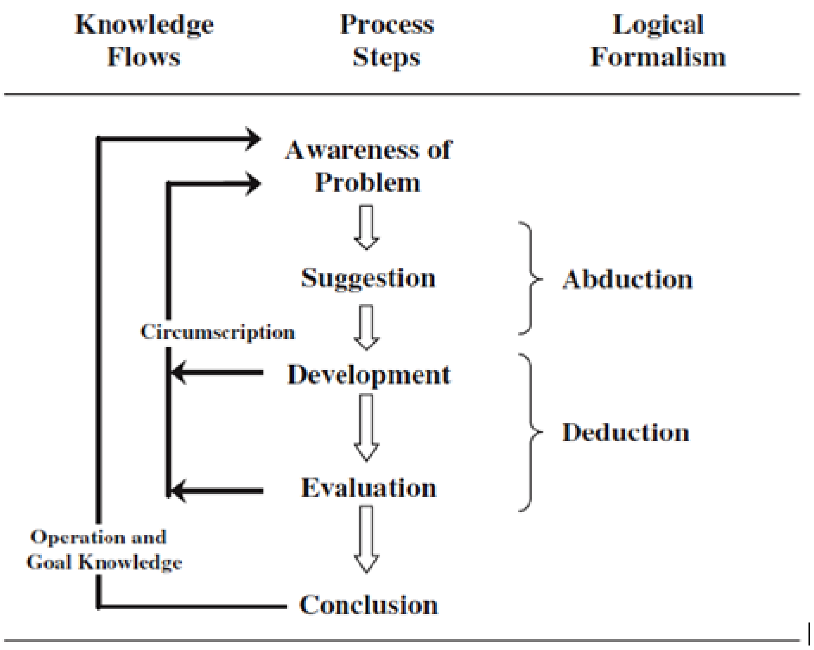

Figure 4.1: The five-step process of design research as proposed by Vaishnavi and Kuechler.

the interview guide, Kuniavsky's structure of an interview was mostly followed [44]. The structure of the questions was divided into several parts: the first part focused mainly on the interviewees' backgrounds (such as testing or research), then it was followed by sections related to the use of technology in general, and the use of the systems and methods we focused on. The interview guide was pilot tested by one person who has experience in requirement elicitation in the automotive industry.

In the second iteration, it was very important to involve experts again to avoid suggesting unnecessary features. We used the same rules which were used in the first iteration to conduct the interviews. The interviews had been structured mainly to receive feedback regarding the model and tool that we had come up with during the first iteration, but also to get suggestions about what types of scenarios to use during the Vårgårda fair. The interview guide was also pilot tested by a practitioner who works in the research department in the case company.

After each round of interviews, we performed content analysis. In the first iteration, we started by writing down our interview transcripts as notes and printing them out. Afterwards, we sorted each note into themes. The themes were not previously defined, but they emerged while we were analyzing each observation. As opposed to the first iteration, where we made separate notes for each statement that a participant gave, we decided that for these interviews, we should group all of the answers that belonged to the same questions together. Then, we chose how to develop our approach according to the answers that occurred most often.

We started the awareness of the third iteration by analyzing the results that we collected from participants during the second iteration.

4.3.2 Suggestion

The suggestion step intends to generate speculative solutions based on the results that emerge from the awareness of the problem from each iteration [41].

In this stage we picked the most important issues and challenges from the content analysis. Our basic suggestion to tackle the issues was to come up with an approach. The approach consisted of a model for the process of eliciting requirements for innovative systems, and a tool whose purpose was to help requirements engineers easily collect contextual requirements for intelligent and interactive systems in vehicles.

In the second iteration the problem became clearer, but building a full solution was complex because we needed to involve end users in our evaluation. We decided to build a prototype for the tool, according to the results gained from the content analysis which we did through the awareness of the problem of the second iteration, and evaluate it with end users during the Vårgårda fair. It was very important to involve end users in this iteration because that would help us avoid creating unnecessary features and to check if developing the tool was worth it. We also suggested updates on the model according to the results analyzed from the interviews that we conducted at the beginning of the second iteration and the supervisors' feedback gained from the first draft of the model during the first iteration evaluation. In addition, we also looked into previous work and research related to creating models for start-up projects and companies.

During the third iteration, we suggested to build the tool prototype into LIV. The main two reasons behind that were that LIV had features (like: speech-to-text, and text-to-speech) that we could benefit from without having to re-implement them ourselves. The second reason was that we wanted to evaluate both LIV (to collect the needed requirements and feedback) and the tool (to evaluate the applicability of the tool) by involving different end users in the process.

4.3.3 Development

In the development phase, the solution suggested in the previous step was implemented. The artifact in DSR might be, for example, implemented software or a low-fidelity prototype. In our thesis we built a low-cost interactive tool. The tool's purpose was to help requirement engineers easily collect contextual requirements for the interactive and intelligent systems in the automotive field. In addition, we built a model to define the process that can be followed when building innovative concepts in the vehicles.

The development of the approach varied significantly between the three iterations that we performed during this thesis.

We believe that developing a model helps bridging the gap between end-users and requirements engineers. This model is suitable for innovation projects because users are not involved at all in the first iteration of the concept development. In the first iteration, the model started with the initial idea step and ended with the feedback and evaluation loop as it included three other processes in between the start and the end processes.

The model was evolved later on during the second iteration. The changes were implemented by adding new stages, and removing some of the stages from the previous version of the process model. The model allowed the researchers or the engineers to choose the suitable elicitation technique according to their point of view.

To develop the tool, we started the development phase in the first iteration by defining the main functionalities that the tool should accomplish, the input and the output of the tool, the tool's users, and why the tool is useful. During this iteration, we created a paper prototype for the tool to be evaluated later on by the Veoneer employees who will later on be users of this tool.

In the second iteration, we created a prototype for the main feature that asks the drivers questions when they are performing a certain action and saves their answers. Due to the time limitation during this iteration and because we wanted to evaluate the idea behind our tool with end-users, we simulated how the tool was supposed to work. We used an online text-to-speech tool to ask a question when the driver performed an action, and a speech-to-text tool when the driver answered, to store the answers.

In the final iteration, we automated the tool and implemented it inside LIV by using Node-RED, a programming tool that is built on top of Node.js, whose purpose is to allow hardware devices to work together [1]. When the users (drivers) performed an action in the system, a question was asked by our tool (through LIV's voice functionality). We also intended to use LIV's speech system for storing the drivers' answers for later analysis, but due to some issues with the microphone, we had to use a voice recorder.

4.3.4 Evaluation

Several methods of evaluation of our artifacts have been used throughout our thesis work. In iteration one, we presented our ideas to both our academic and company supervisors in the form of a PowerPoint presentation. Afterwards, they gave us feedback, which we used as a starting point for our second iteration.

During the second iteration, we used evaluation for two purposes:

[1] Source: `https://nodered.org`

a. To evaluate our tool.
b. To evaluate LIV.

In order to evaluate both our tool and LIV during both the second and the third iterations, we conducted a usability test with end-users. After the usability test, we also distributed questionnaires to the participants. The answers that they gave helped us understand how they felt about both LIV and our tool.

The evaluation of the third iteration was performed in the same way as it was in Iteration 2.

4.3.5 Conclusion

According to Vaishnavi [41], the conclusion phase is used to decide whether you need more iterations in order to accomplish your research effort or whether the current iteration marks the end of your research effort.

During our thesis, we have conducted in total three iterations. After the first two iterations, we decided that there was a lot of room for improvement in our approach towards requirements elicitation. The third iteration helped us see that what we developed was valuable to practitioners. However, we believe that our approach could be further improved by using more iterations.

4.3.6 Findings

After each iteration that we conducted during this thesis, we finished it by concluding our findings. This helped us take decisions and suggestions for the next steps. The findings are listed as follows:

First iteration's findings

- Most of the concepts that researchers in the company develop are innovative.
- End users are not involved in the very beginning of an innovation project.
- The interviews are a good inspiration way to develop the innovative model.
- Face to face interviews are helpful in bridging the gap between the academic terms and industry terms.
- The innovative idea enriches by following the steps of our model, and iterating until you have a list of concrete ideas to develop.
- The solution should fix the issues which are collected during each iteration, and it also should include the system prototype and involve the end users.

Second iteration's findings

- The user of the model should not be limited to use a specific requirements elicitation technique.

- Collecting requirements by allowing the users to use the system's prototype in the car (in the right context) is more efficient compared to collecting requirements in a different context.

Third iteration's findings

- It is important to make sure that the system and its features is explained in such a way that both people with experience in using software systems in vehicles and people who do not have so much experience in that field understand the features. This way, they will provide insightful feedback.
- The diversity in choosing the end users to evaluate the system and the tool is important to collect different points of view.
- When the car is standing still, it is important to give drivers examples of scenarios of how a certain feature would work. This would make it easier for them to understand that the tool is useful.

4.4 Summary of the data collection during the iterations

Table 4.1 explains how and what data has been collected for each DSR stage during the three iterations.

Iteration	Awareness of the problem	Suggestion	Development	Evaluation	Conclusion
Iteration 1	• 4 interviews. • Literature review on requirement elicitation techniques problems and challenges in automotive system. • Interviews analysis.	Our approach consists of: • A tool: to help requirements engineers easily collects contextual requirements. • A model: to help in eliciting requirements from users for innovative projects.	• First sketch of the model. • A concept for the tool.	• Academic supervisors. • Industry supervisors.	• The need to take the technicians and researcher' point of view regarding the suggestion.
Iteration 2	• 5 interviews. • 1 technical interview. • Interviews analysis.	• Changes on the model and adding new processes. • Changes on the tool features.	• Second sketch of the model. • A prototype of the talking functionality of the tool.	• Evaluate the model during the company presentation. • Evaluate LIV and the tool using 29 end users.	• The need to implement the tool.
Iteration 3	• The analysis results of the end users' Feedback gained from the second iteration.	• Use LIV features to implement the tool.	• Implement the tool inside LIV.	• Evaluate LIV and the tool using 57 end users.	• Suggestions for future works regarding the proposed solution.

Table 4.1: A summary of data collection of DSR stages in each iteration.

5
Iterations

In this chapter we present and discuss in details how we conducted the three iterations of this thesis.

5.1 First Iteration

The purpose of the first iteration was to inspect the requirement elicitation problems and challenges in interactive and intelligent systems for autonomous vehicles from employees with expertise in requirements engineering and from literature in the same domain. In addition, this iteration aimed to propose solutions to solve the discovered issues.

5.1.1 Awareness Of the Problem

We started the first iteration by conducting a literature review on requirement elicitation techniques problems and challenges in automotive systems, in addition to studies related to human centred design issues and studies of different types of requirements and their elicitation techniques. Then we moved to learn more about the features of the LIV research platform, and what the researchers in the company want to achieve with it. This iteration also consisted of discovering the main issues that researchers in Autoliv encountered while eliciting requirements and providing a solution to those problems.

Four participants were interviewed in order to discover problems related to requirements elicitation, all of whom were employees at Autoliv. All of the participants worked mainly in the Human Factors department and their experience ranges between 6–24 months.

The interview was structured in four parts, with general questions about the participants' experience and projects that they had previously worked on being the first one. Questions about the requirements elicitation process in general were the second part. The third part focused on the various elicitation techniques that the participants had used in their projects in automated systems. Finally, the fourth part focused on the issues and challenges that the participants faced during requirements elicitation. The interview questions can be found in Appendix 1.

Before conducting the interviews, we ran a pilot test with a business analyst that is

Figure 5.1: The themes that emerged during the content analysis.

not employed by Autoliv or Veoneer, but works for an automotive Swedish company in Gothenburg. His responsibility is collecting requirements for new services from customers. The interview was conducted within 53 minutes, and two duplicated questions and one unclear question were revealed. In addition, two additional questions were discovered. As a result from the pilot test, we removed the duplicated question and rephrased the unclear one. Some questions were also re-ordered according to how the interviewee answered the questions in the pilot test and two new questions had been added to the interview questions.

It is important to take into account that the results of the analysis come from Veoneer Research. Since we have not interview anybody from the development department, we cannot draw any conclusions about how they elicit requirements or what issues and challenges they face.

5.1.2 Interview Analysis

We used content analysis to analyze the interviews. Fourteen main themes arose during this process process. Two of the themes, i.e. "Elicitation Techniques" and "Elicitation Techniques Challenges & Issues" had between 9 - 11 sub-themes. An overview of the clustering result can be seen in Figure 5.1

The analysis outcome

- Avoided methods Upon analyzing all of the interviews, we discovered that there were no methods that the interviewees avoid, but they did choose their methods according to the type of project that they were working on and what said project entails. However, a few observations are worth pointing out:
  a. One interviewee mentioned that they trust the actions people perform more than what they say.
  b. One interviewee said that they do not work with only one method.
  c. Interviewee is reluctant to methods where researchers have to "come up with data themselves", for example methods such as personas, where the researchers come up with profiles of their target users, or bodystorming [45], where researchers pretend to be users. It is important to mention, however, that the participant has never used either of these methods.

- Importance of User Involvement The most recurring issue that was discovered during the interviews was the involvement of end users during the development phase of the research vehicles. Only one of the four interview participants involves real users in their tests. As far as the other three participants are concerned, when it comes to evaluating an idea or a prototype, they only use other employees at Autoliv, often from the same department as them. This can be problematic, because it means that the test participants might have a certain bias towards the tested prototype, since they are also working on the same project. It also means that there is a lack of diversity amongst the participants. For example, there is a lack of diversity in terms of age, since the participants are most likely older than 20 and younger than 70. The only times when they have the opportunity to test their concepts on real users is during conferences, such as CES (International Consumer Electronics Show). Nevertheless, all of the interviewees agreed that involving real users is very important for these types of projects, and they voiced their concerns about the lack of actual user testing during the development of a concept. We want to emphasize, though, that these results are true for the research department at Autoliv (and now Veoneer), and since we did not interview anyone from the development department, we cannot draw any conclusion about how much they involve end-users.

- Collected data Data can come in two forms: quantitative and qualitative. Quantitative data is the type of data which can be somehow converted into numbers, while qualitative data is the type of data that comes in the form of patterns that have emerged during discussion-based research, or ethnographic research. All of the interview participants said that they aim to have both types of data during their research. However, one interviewee said that most of their focus is on qualitative data, while another said that they tend to focus mostly on quantitative data (i.e. accident data). The other two interviewees said that they collect both types of data in equal amounts because:

a. With having only one type of data, a conclusion can not be reached.
b. Data types are not always related. For example, when comparing two products, quantitative data might show that one product is better, but qualitative data can reveal that the other product is much easier to use.

Regarding data, two main issues were discovered:

a. It often happens that there is not enough data to draw conclusions from.
b. It is dangerous to look into data that does not come from end-users.

- ELICITATION TECHNIQUES USED The elicitation techniques used in Autoliv are explained in details in Table 5.1.

Elicitation technique	Description
Interviews	• Always used when there is something to show and ask feedback about. • Interviews are always semi-structured. • The interviews are used for validation in some cases. • They can be conducted in a formal or informal setting. • Sometimes interviews are conducted randomly.
Questionnaires	• Questionnaires are used for evaluation purposes. • Sometimes they use questionnaires to get new ideas. • They always perform pilot tests before conducting the questionnaires with users.
Prototyping	• Used because people don't know what they want before they see a prototype. • Prototypes enable iterations. • Interviewees use prototypes when they want to test concepts on users. • Prototypes are used in order to understand what users need rather than what they want.
Focus groups	• Used when discussions are needed. • Used to get an overview of a certain concept.
Driving Simulator	• They use it for testing because it is safe.

Instrumented Cars & Controlled Environment	• They are useful in providing users with an experience that feels real. • They are used because they allow the tester to control the test.
Personas	• Personas are not used at all. • One interviewee was skeptical about this method.
Think-aloud	• This method is used to understand how people think and act when using a concept. • Used to understand why people perform certain actions.
Combined methods	• All of the methods previously presented (except personas) are used with prototypes. • Prototyping is the main elicitation method.

Table 5.1: Autoliv's elicitation techniques

One method in particular that stood out is the one we called "Combined Methods", i.e. methods from Table 5.1 that are used together. From this, we understood that prototyping is the most important elicitation method that is used in the company. The other methods are mostly used as mechanisms to gather feedback on the prototype.

- **Elicitation techniques Challenges and Issues** The elicitation techniques issues and challenges which were discovered through the interviews are explained in details in Table 5.2.

Elicitation Technique	Issues and Challenges
General Issues	• It is hard to involve end-users. • It is very difficult to test on real roads, which is why, when testing, one is forced to use simulators or test tracks.
Prototypes	• If the technology is not working, or if setup is only half-finished, people will only focus on what doesn't work.

Observations & Think-aloud	• It is difficult to get a natural reaction from drivers, because they might feel self-conscious during the test. • If there is not enough time available, it is difficult to build trust between driver and tester.
Questionnaires	• It is difficult to put trust in the questionnaire. • Questionnaires are difficult to analyze - either due to missing data or open answers.
Rapid Prototyping	• It is difficult to incorporate the right amount of iterative loops in the development chain.
Driving Simulator	• It is difficult to simulate real situations. • It is difficult to use when it comes to certain situations such as drowsiness.
Cars and Controlled Environment	• If there are many repetitions in a test, then the user will become accustomed with the situation which can lead to invalid experiences.

Table 5.2: Elicitation techniques challenges and issues in Autoliv

After categorizing all of the notes and observations that we gathered from the interviews into themes, we chose the ones that we believed were most relevant for this iteration and summarized the notes from each one (Figure A.1 in Appendix 1).

From the resulting themes, we chose to focus our attention towards the issues that were the most urgent. These issues are:

a. **P1.1** - The difficulty of providing participants with a *natural experience* while driving.
b. **P1.2** - *Data-related issues*, i.e. there is not enough data, there is a need for both quantitative and qualitative data, and the data might be difficult to analyze.
c. **P1.3** - There is a lack of *real user testing and diversity* among the participants that take part in the testing. The only people that get to test the concepts are employees at the company. We believe that this could introduce bias in the evaluation, since both requirements engineers and participants come from the company, and in some cases they even work on the product.
d. **P1.4** - There is no methodology used for choosing the target audience for the testing in such a way that a diverse population is used to evaluate one product.

5.1.3 Suggestion

To solve the four issues that were mentioned in the previous section we decided to come up with a tool which has the purpose to help requirements engineers to easily collect requirements for intelligent and interactive systems in vehicles. In addition, from the experience that we had had thus far in the company, we decided to create an innovation model that would help them gather feedback and elicit requirements from users for innovative projects. Since most of the concepts that the researchers in the company develop are innovative, they do not involve users outside of the company in the project, because users might not know what they want before they actually see the product and because the idea might be leaked too early. While it makes sense to not involve real users in the very beginning of an innovation project, users must be involved at some point in the process in order to make sure that the concept that you are building meets their needs. Since prototyping is one of the main methods used at the company, we decided that our solution would also involve the prototype in one way or another. In addition, our solution would also aim to solve the issues presented above. The following sections describe how we aimed to do that.

5.1.4 Development

5.1.4.1 Suggested process model to be used

To address the issue **P1.3**, we proposed **S1.1**: a model that helps to both bridge the gap between end-users and requirements engineers and eliminate the risk of leaking an innovative idea too early in the process.

The model, which consists of five main steps, is suitable for innovation projects because users are not involved at all in the first iteration of the concept development. However, the feedback that has been gathered from users during the Evaluation & Feedback stage will serve as input for the second iteration in order to make sure that the product meets their needs while providing a great user experience. Figure 5.2 depicts a rough first version of our model.

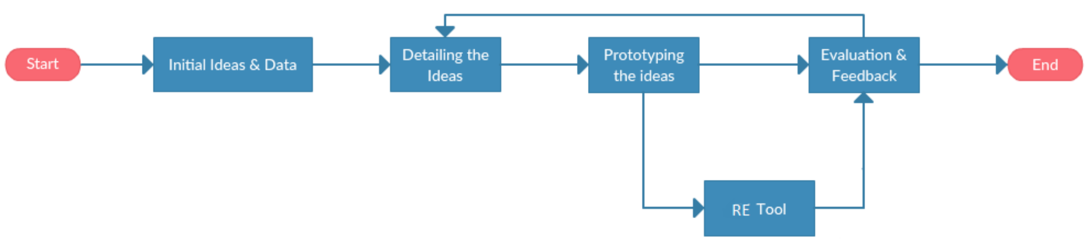

Figure 5.2: The innovation model that we came up with during the first iteration.

1) Initial Ideas & Data

The first step in the process is to come up with the initial idea for a new concept. This idea can be very broad or abstract. We propose that these ideas should be generated by brainstorming, discussions within the company, or ideation techniques, such as Random Links, for example [53].

2) Detailing the ideas

In this part, the initial ideas are turned into more concrete ideas, without wasting time in detailing very deeply. This can be done via techniques such as brainstorming, focus groups, or ideation techniques.

3) Prototyping the idea

As mentioned before, during the interviews, prototyping has emerged as the central elicitation method for all interviewees. Because of this, the prototype will be an important step in our model and what our tool will be used in close connection with. The prototype should be developed in such a way that it fulfills the ideas that emerged during Steps 1 and 2.

4) Concept for RE tool

The RE tool helps in collecting contextual requirements, and more details about the tool are in Section 5.1.4.2.

5) Evaluation & Feedback

The final step in the model is Evaluation and Feedback. Using the tool that we plan to develop, researchers and requirements engineers at Autoliv should be able to test on end users and gather feedback from them. Section 5.1.4.2 provides a detailed description on how that would be done.

Once step 5 is finalized and the feedback is evaluated, the requirements engineers can either finalize the development of the concept, or go back to step 2 and come up with new ideas based on the feedback that they have received from users during the Evaluation step.

5.1.4.2 Concept for Requirements Elicitation Tool (RE tool)

The purpose of the tool is to help Requirements Engineers come up with requirements from feedback and observations that are gathered while a user is driving the car and testing the system. The tool has the following main goals:

a. **S1.2** - Collect data (both quantitative and qualitative). This helps solve **P1.2**
b. **S1.3** - Capture users' reactions in certain situations and under certain conditions. This partly solves **P1.1**.

c. **S1.4** - Create a list of relevant personas to help researchers gather appropriate participants for their tests. This represents a solution for **P1.4**.
d. **S1.5** - Make participants comfortable, by eliminating the need for a requirements engineer to observe them in the car, in order to capture a real and natural experience. This is the answer for **P1.1**.
e. Support for analysis of the gathered data.
f. Support for generating a list of prioritized requirements.

How the tool works

Input - the input to the tool will be a list of pre-configured questions that will be asked while the participant is performing the test. These questions will be asked by the researcher or requirements engineer who is conducting the test.

Personas generation - the tool shall generate a list of personas that requirements engineers can use to ensure that they include a diverse and large enough test population.

Making use of the sensors in the car - in order to get the real experience and reactions from the participants, the sensors in the car - which can be found in Table 3.1 - must be used, so our tool will be using them to:

a. capture specific situations - some questions could pop up when the driver performs certain actions in certain situations, such as turning up the volume or speed, or braking all of a sudden. This is important because it will help us gather reactions and requirements in real time. To accomplish this, the tool can use, for example, the DMS functionality of LIV to see what the driver is focusing on.
b. capture context - questions can also be related to the participants' environment, both inside and outside the car, such as weather conditions or blind spot sensors. While it might be difficult for a requirements engineer to know when to conduct tests in order to capture participants' reactions in any specific situation, the tool will be able to capture them because it is running all the time.

Data collection and analysis - the answers that the participants provide will be collected and saved in a database and then the data will be analyzed. The purpose of this analysis would be to support requirements engineers in writing a requirements specification.

Output - based on the data collected, the output will be a list of high level requirements.

Why the tool is useful

This tool aims to be useful for three main reasons:

a. It will save time for the Requirements Engineers because they will not have to physically be in the car when the participant is driving, and they will not have to collect and analyze the data by themselves.
b. It will enable the requirements engineers to have access to a large audience.
c. It collects requirements in specific situations and circumstances, which the requirements engineers may skip because they cannot be available for long time with the user to catch these situations.

The stakeholders of the tool

The tool has two main stakeholders:

- *requirements engineers* who want to elicit requirements for intelligent and interactive systems in autonomous vehicles. They are the main users of the tool.
- *driver* who take part in usability tests in the car.

The tool would help both of these stakeholders by providing a natural setting. For the RE, the feedback will be more authentic, and the drivers would not feel like they are being watched all of the time during a test.

5.1.5 Evaluation

The model and concept of the tool was presented both to our company and academic supervisors. The company supervisors gave us positive feedback, saying that both the model and the tool would help them during the concept development process. Our academic supervisors suggested some modifications which generally focused on:

a. Modifying the model and expanding some of the steps in the model.
b. Looking into other stakeholders of the system apart from the end users (for example OEMs).

5.1.6 Conclusion

The first iteration helped us understand what the main problems are when gathering requirements for intelligent and interactive systems in autonomous cars. This was done by conducting semi-structured interviews with four researchers from Autoliv, all of whom work within the field of Human Factors. We performed content analysis on these interviews and came up with the most important problems. Finally, we came up with a very rough idea of a model for the requirements elicitation process for innovative systems and a tool for requirements elicitation. In the second iteration, we plan to conduct more interviews in order to refine our model and tool by discovering what modifications we should make to improve the model and what researchers at the company - and Requirements Engineers in general - would expect to gain by using our tool.

5.2 Second Iteration: Enhancing the approach and collecting requirements

This iteration focused on enhancing the model built in the first iteration and developing the main functionalites of the tool, which was also proposed in the first iteration. The enhancement was based on the feedback collected during the evaluation of the first iteration and the interviews of the second iteration. In addition to that, in this iteration we prepared a scenario to participate in the Vårgårda fair, which would help us in evaluating the proposed tool by collecting requirements for the LIV system from the fair visitors.

5.2.1 Awareness Of the Problem

During this phase we analyzed the feedback from the first iteration evaluation, as we received different points of improvements related to both the model and the tool. We grouped all of the feedback in two main categories as explained in Section 5.1.5.

Based on this feedback, we prepared an interview guide to know more about the unclear parts in the model and how we could steer it more towards innovative projects. In addition, we used the interview to check which of the functionalities were most valuable to be implemented in the tool, so we could prioritize our work. To achieve that we conducted structured face-to-face interviews.

In this round of interviews, since the questions were related directly to the model and the tool which emerged as a solution from the first iteration, we used the first interview from the conducted interviews in this iteration as a pilot test. As a result from the pilot test, we rephrased unclear questions. Two sections of the questions were also re-ordered according to how the interviewee asked questions to understand the work flow in the model.

The interview consisted of five parts, with general questions about the interviewees' experience and projects that they had previously worked on being the first ones. The second part was questions about the model. Here, we mainly tried to collect information about which parts of the model have issues, to check the clarity of the model flow, and to gain the interviewees' suggestions and feedback. The third part focused on the tool's functionalites, i.e. which ones were the most important and why, and suggestions regarding the tool input and output. The fourth part was technical questions related to the car connectivity, and the programming languages and databases that the interviewees had used in their previous projects in autonomous systems. Finally, the last part focused on the Vårgårda fair, as we collected in this part different scenarios and pieces of advice from the interviewees' experiences and their previous participations in such fairs.

Analysis Results

After we gathered all of our interviews, we performed content analysis on them. The most important points that arose from the analysis were:

a. *For the model:*
- It is good that we have an iterative feedback model.
- The model works for innovative projects, problem solving and answering research questions.
- There is an issue with the wording, and it was suggested that we have only one word per bubble.
- It was suggested that we should add some wording on the arrows, in order to know how to get from one step to another.
- It was suggested that we should not include a specific requirements elicitation tool in the model.
- It was suggested that we should make the loop clearer to the reader.

a. *For the tool:*

(a) Personas functionality:
- Interviewees liked the idea of incorporating a persona functionality in our tool.
- Most interviewees said that they would like an equal distribution of age and gender.
- Driving experience, how often people drive, in which areas (highways or inside cities), and in what country they drive is very important for participants.
- There were also certain characteristics that were mentioned only once by an interviewee, e.g. whether a driver is hearing or visually impaired.
- The interviewees also do not want to involve people who drive for less than certain amounts of hours a month.
- The interviewees would like to categorize the persona characteristics as "Must have", "Should have", or "Nice to have".

(b) Capturing data in its context, connecting to sensors, and using a camera:
- Depending on what sensors you need to gather the data from, it could be difficult to connect to them.
- In order to capture the context, you need external driver monitoring systems, e.g. to see if they are focusing on the road ahead. You could also monitor physiological measurements.

- All of the interviewees said that it would be good to use a camera, but they would not rely entirely on it, because you can catch things by observation that you cannot catch using a camera.

(c) Prioritizing the requirements

- For the company, safety is the highest priority.
- Most interviewees said that usually, they prioritize requirements by analyzing everything that they have to do, and they were not fond of the idea of having a tool that prioritizes requirements for them.

(d) Stand-alone vs. built-in tool

- Most interviewees were torn between a standalone tool and an integration into LIV.
- The interviewees mentioned that if the tool were integrated in LIV, the researchers would be able to get much more insightful data.
- The interviewees also said that the tool should be integrated because LIV already talks to the car for actions and those actions should be examined or tested.
- However, the interviewees also mentioned that an embedded tool would be very difficult to implement.
- They also said that they would like the tool to be standalone because they would like to use it with more than one concept.

b. *For the fair:*

- We should think of a scenario that can be done while the car is not moving.
- We should have the driver imagine a situation that they are in when they have to use the car, e.g. being in an airport and trying a car that has LIV incorporated in it for the first time.
- We should focus on certain features and compare the reactions of the drivers.

Finally, we prioritized the points that were most important to us and decided to focus on those. These points are:

- **P2.1** - The wording in the model is unclear, both for the actual steps and the arrows that lead to those steps.
- **P2.2** - The steps when users are not included in the model and the ones where they are unclear.
- **P2.3** - For the persona functionality, there are some features that all of the interviewees use when selecting test participants. At the same time, there are some features that were asked for by only one interviewee.
- **P2.4** - An integrated tool would help interviewees collect more insightful data for one system. However, a standalone tool would not lead to such insightful data, but would be usable with all of the concepts that they have.
- **P2.5** - For taking the context into consideration, one could use driver monitoring systems for physical measurements and for noticing where they are

looking.

- **P2.6** - Requirements are prioritized by analyzing everything that they have to do. Interviewees were not fond of automating the process of prioritization.

5.2.2 Suggestion

After we performed our analysis, we came up with the following suggestions, which we believed were most valuable both for our industry collaborator and for our research:

- **S2.1** - To address the issue in **P2.1**, we changed the names of the phases in the model.
- **S2.2** - We made a clearer separation between the feedback loop and the phases where users would not be included in the model. This would solve the issue raised in **P2.2**.
- **S2.3** - Our tool would be integrated in LIV. This is the decision that we made in relation with **P2.4**. For now, it is more important for us to gather more insightful data from LIV than to have a standalone tool. In addition, making an integrated tool would allow us to use LIV's text-to-speech and speech-to-text functionality and LIV's functionalities (seen in Table 3.1) in order to get more accurate feedback and collect data about the driver, as mentioned in **P2.5**.
- **S2.4** - To address **P2.3**, we have decided that the personas functionality will have some categories which will be implicit (age, gender, biography), but the requirements engineers will also have the chance to add categories that they believe are important.
- **S2.5** - Regarding **P2.6**, we have decided that there will not be a requirements prioritization phase, because all of the engineers that we interviewed had different opinions related to how they would prioritize, but agree that most of the time, it depends on the project that they are working on (e.g. for LIV, they prioritize features that would increase the safety of the driver). Because of this, we decided that we will not incorporate a prioritization feature in our tool.

5.2.3 Development

We started working on evolving the model by looking at the analysis results and previous research that focuses on models in startup projects or startup companies. Figure 5.3 depicts the updated version of the innovation model.

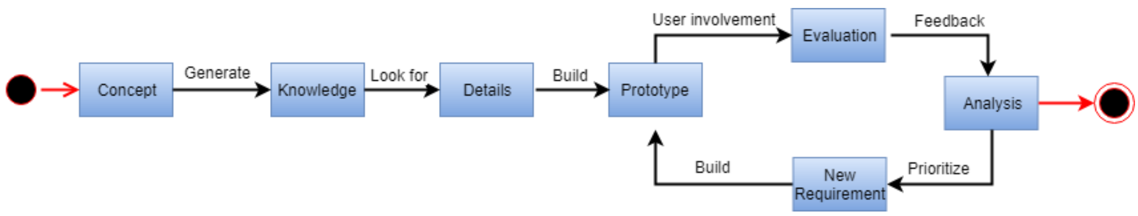

Figure 5.3: The second version of the innovation model.

According to the analysis, we fixed the wording and replaced some of the words and expressions in the first model with clearer words, and some words had been rephrased. So now we only have one clear term for each box (process). We also named the arrows (actions) to keep the action between two processes clear. We changed the loop which contained (prototype the idea, Evaluation and feedback, and RE tool) to be:

Prototype → User involvement → **Evaluation** → Feedback → **Analysis** → Prioritisation → **New requirements** → Build → **Prototype** (circle).

Below is an explanation of each step in the model:

- **Concept** - an initial idea for an innovative system. It can be something as abstract as "a talking car".
- **Knowledge** - once you have a concept in mind, you *generate* more knowledge about how the concept can be achieved.
- **Details** - after you have the knowledge, you can *look for* further details. These details can be seen as some tasks or functionalities to accomplish the knowledge.
- **Prototype** - As soon as you have all of the details and knowledge that is needed in order to create the concept, you should *build* a low fidelity prototype for your concept.
- **Evaluation** - this is the point where you have to *involve users* in order to evaluate your prototype.
- **Analysis** - with the *feedback* that you have gathered during the evaluation, you can start evaluating your data.
- **New Requirements** - once you have analysed your data, you can create a *prioritized* list of requirements.
- Finally, using the new list of requirements, you can *build* an updated **prototype** and start the loop again.

In addition, because we do not want the model to be limited to a specific tool, the "RE tool" process from the previous sketch of the model is now included in the "Evaluation" process. Hence, in this version of the model, the requirements engineer chooses the suitable way to evaluate the prototype and to involve the users in the evaluation process.

In parallel, we were preparing to participate in the Vårgårda fair. We came up with a scenario for the fair. This was done together with a Bachelor student from the University of Skövde who was doing her Bachelor thesis on a topic related to LIV as well, focusing on creating trust. The scenario had two purposes: to evaluate LIV and elicit requirements for the company and to evaluate our tool. The plan was to first see whether users would like to have LIV asking them for feedback at all, before implementing our tool into LIV.

For our first prototype, we wanted to develop the speech-to-text and text-to-speech functionality by ourselves and then test it during the Vårgårda fair. After doing some research about how we could implement that, we decided that we would do it in C#, because they provide a library for both text-to-speech and speech-to-text conversion. After we implemented it, we noticed that you had to speak very slowly and very clearly for the program to be able to understand you, as such algorithms should be intelligent and keep learning by themselves. Because of this, we decided that instead of implementing something for the prototype, we would use online tools. For text-to-speech, we used Natural Readers [1], which is an online tool that speaks out the text that is input. For speech-to-text, we used an online tool called Dictation [2], which was developed using Google's Speech Recognition API. In addition, we used a GoPro camera to capture all of the participants' reactions.

We decided that we would be using a questionnaire, dictation tool, and video and audio recording in order to store our data during the fair. In preparation for it, we also created a poster and a video that was used to advertise LIV, an ethics document to be given to the test participants, and the questionnaire which we would use to evaluate LIV and our tool. Figure 5.4 presents the poster advertisement that we created for the fair in order to increase the number of participants in our study. The poster was created in collaboration with the other bachelor student.

Figure 5.4: The logo which was used in the Vårgårda fair.

There are three major phases in the scenario. Figure 5.5 contains all of the steps in the scenario.
In the <u>*first phase*</u>, which took part outside of the car, we showed the participants a video introducing the main purpose of LIV and some of its features. Figure 5.6 shows how the video, which we created to present the LIV research platform, was

[1]Natural Readers link: `https://www.naturalreaders.com/online/`
[2]Dictation link: `https://dictation.io/`

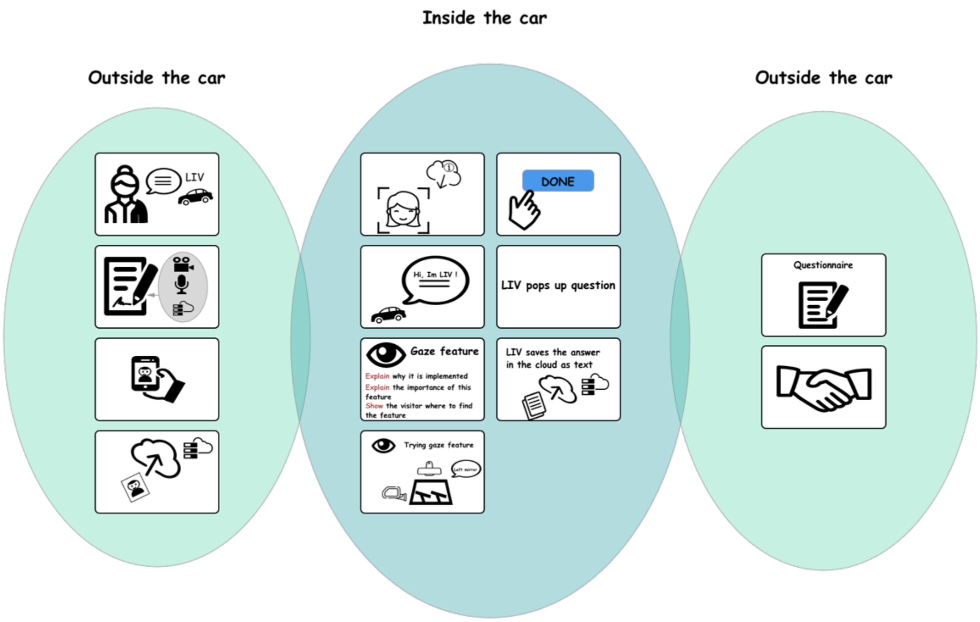

Figure 5.5: The designed scenario that we will follow in the fair, in cooperation with the Bachelor student.

shown to the participants. During this phase, we also asked each participant to sign

Figure 5.6: A video of LIV that was presented to the fair participants.

an ethics document in which they gave their consent for storing all of the data that would be gathered from them (except personal information) during the test. Finally, they were requested to register in the LIV mobile app. The registration consisted of them creating an account using their name and taking a selfie. This would be used in order to allow LIV to recognize them when they first entered the car. Figure 5.7 presents the LIV app that we used in the fair to register the participants in the cloud server in order to allow LIV to identify them when they are in the driver seat.

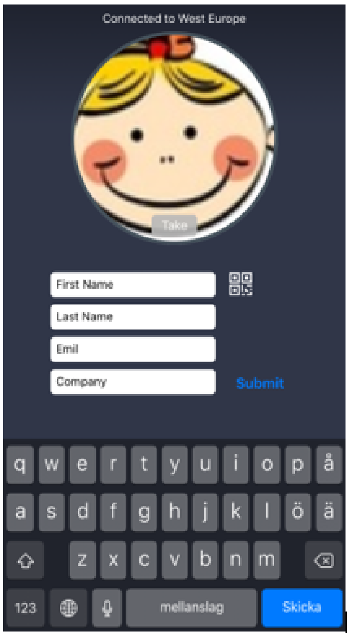

Figure 5.7: LIV's app.

The *second phase* took place inside the car. After the participant entered the car and LIV greeted them, we showed them various features that were already available, such as seat adjustment, night-vision, zForce [3], or seat-belt adjustment. We also showed them the gazing feature. This feature allows LIV to know where the driver is looking, e.g. left mirror or wind shield. LIV uses this to give the driver useful information by understanding where the driver is looking, but also understanding where objects on the street are located. After the driver tried the gaze feature, our prototype of the tool popped up a question about it (using the Natural Readers tool). When the driver answered, we used Dictation in order to store what they said as text.

The *third phase* was outside the car again. In this phase, we asked the participants the questions from our questionnaire (Appendix 3), and thanked them for taking part in our study.

[3] zForce is the steering wheel that LIV uses, which contains touch detection, light feedback, and gesture detection.

5.2.4 Evaluation

The model has been evaluated by our company supervisors. The feedback we received was positive, as they liked the fact that we were inspired by different approaches found in literature and models for start-up companies. They also liked that we updated some steps by giving them clearer names, and included some additional ones in order to make the model more clear and easier to understand.

During the fair, we evaluated our tool in two ways. The first way we used to evaluate the idea was by asking the users about their feelings when the system was asking them questions about its features ("Do you feel comfortable that the system will ask you about its features?"). The response for this question can be seen in Figure 5.8.

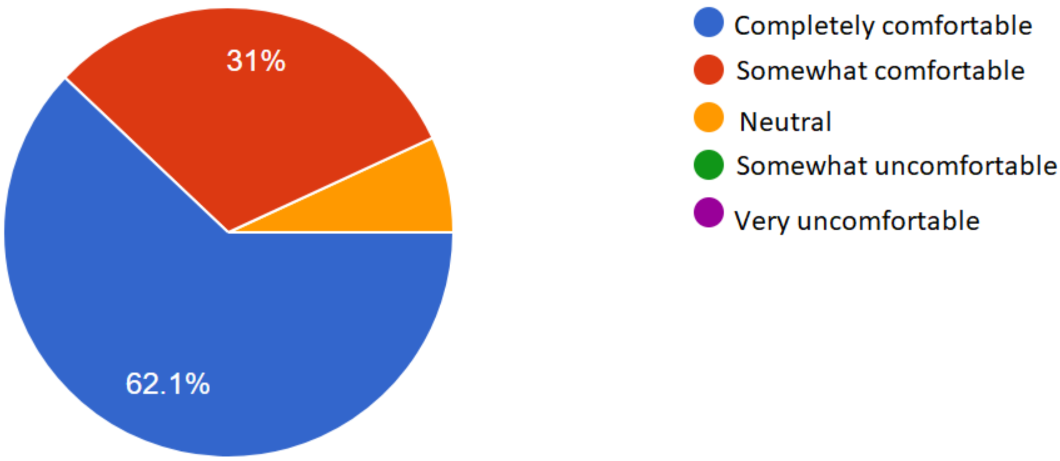

Figure 5.8: The feedback of the fair participants on the tool.

We can see from the figure that the answers are distributed between three categories (Completely comfortable, Somewhat comfortable, and Neutral).The majority of the participants (18 out of 29) would be completely comfortable to be asked by the system about the features while they are using them. They believe that the system questioning them is a fast way for them to express what they like and what they would like to update in the system. At the same time, (9 out of 29) of the participants seemed to be somewhat comfortable to that. Some of the suggestions we received were to have a limited number of questions, choose the right timing to ask them, and not ask the questions in a continuous manner (instead, ask them from time to time). The second way was to use the tool while the participants were trying the LIV prototype, as shown in figure 5.9.

We concluded the pros and cons related to the tool. The positives that we recognized were that participants seemed to be comfortable with the fact that a system asks them questions that they have to answer. The tool could also ask the questions in different languages which removed the need for us to translate. Hence, for later use for the tool, that will make it easy to be understandable so we can reach drivers

Figure 5.9: Evaluating the tool with the participants during the Vårgårda fair.

from several backgrounds. The negative aspects that we collected is that there was a risk that the question was not clear to all of the participants, and some needed a human interference to clarify it. Furthermore, the tool could not capture all the answers correctly because of the different dialects that the participants had.

In addition to all of this, we used the questionnaire in order to collect requirements about LIV. We received 30 responses, which we later on analyzed. After the analysis, we came up with a list of functional and quality requirements regarding LIV which we stored in the form of user stories. As the goal was to evaluate the process and the tool, the full list of requirements will not be included in this thesis.

In general, the participants suggested new features, like:

- Functional requirements:
  - LIV shall have maps.
  - LIV shall have voice GPS commands.
- Quality requirements:
  - LIV shall have solid colours for the display.
  - LIV shall keep the driver's data private.

We also used the questionnaires to evaluate LIV and see how people feel about its features. We did this by analyzing the answers in an Excel spreadsheet. We looked at how different groups of people (based on gender, age, and time spent driving) felt about the features of LIV.

We have recorded the gender because we were studying the qualitative side of user requirements, gender and thus gender roles as part of priorities may play a role, according to a study conducted by Bellet et al. [54] to analyze the difficulties experienced by drivers regarding gender from the same age, and to identify their needs and their expectations regarding ADAS. The study's conclusions are that many driving cases were checked as significantly more difficult to perform by the female than by the male, and both men and women have a positive characteristics towards driving aid systems [54]. We recorded the age as it plays a role in the qualitative point of view. A study conducted by Trübswetter et al. [55] to examine the knowledge, experience, and barriers toward the use of ADAS in the elderly and to compare these to young drivers concluded that older drivers ask for help in learning to use new technologies as well as they need support to get information about the benefits from using ADAS. We also analyzed our answers according to drivers who spend a large amount of driving time.

In general, most responses seem to be open to a concept such as LIV. However, as one example from the analysis list we accomplished, we noticed that respondents have mixed opinions about the "social" aspect of LIV. Figures 5.10, 5.11, 5.12 show the various responses that we received based on age, gender, and time spent driving.

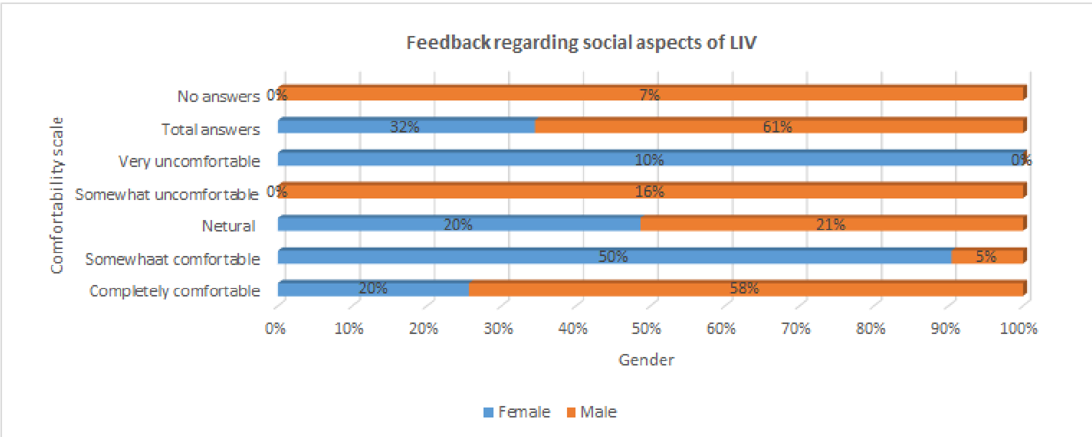

Figure 5.10: Feedback regarding social aspect of LIV categorized by gender of respondents.

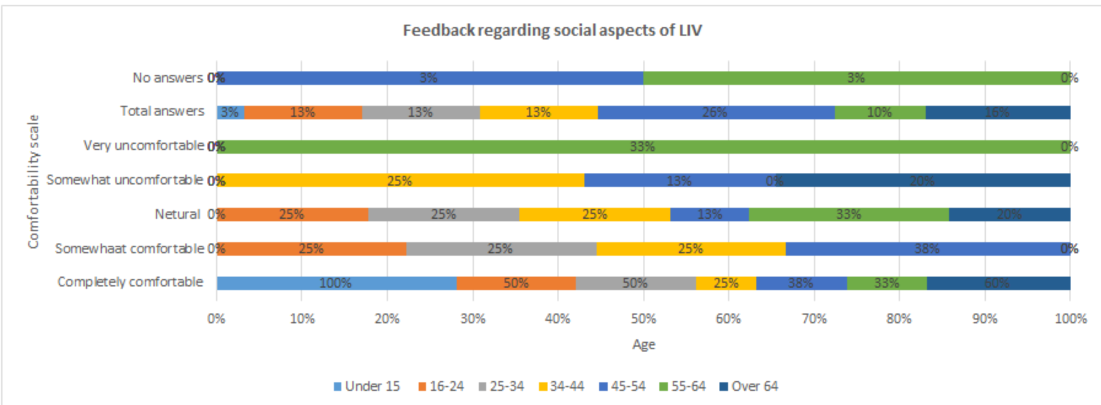

Figure 5.11: Feedback regarding social aspect of LIV categorized by age of respondents.

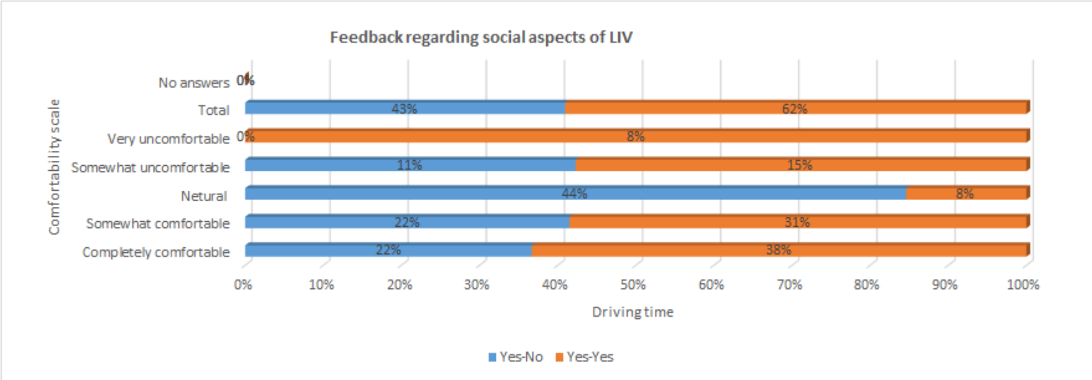

Figure 5.12: Feedback regarding social aspect of LIV categorized by time spent in driving of respondents.

5.2.5 Conclusion

In this iteration, we evaluated LIV and learned that most people are open to the idea of a car that talks to them and assists them while driving. We also learned that participants seem to be comfortable with the system asking them for feedback. We also learned that our model and tool could be highly valuable to the company. After performing our usability tests during the fair, we believe that the following updates would be valuable:

- The tool should support different languages both in the speech-to-text and text-to-speech processes.
- The tool could ask the driver to confirm the answer, by repeating it and asking for confirmation.
- The requirement engineer should add short questions and make sure that they are easily understandable.
- The tool should have the options to repeat the questions according to the driver preferences.
- The tool should give the driver the option to skip the questionings part.

During the test, we collected a list of requirements and we analyzed the questionnaire's answers in order to hand the analysis to the company. In addition to that, we collected lessons learned through our participation for the first time in such fairs. These lessons would be very useful for us for the next conference in which we would participate during the third iteration.

As far as the persona functionality of the tool is concerned, we did not have time to develop it further due to the preparations that were necessary for the Vårgårda fair and because we believe that the speech functionality of the tool is more important than the personas. However, we still believe that the persona functionality constitutes an important part of our approach and we discuss how we would plan on continuing with it in Section 7.2.

5.3 Third Iteration: Enhancing the tool and collect requirements for LIV

5.3.1 Awareness Of the Problem

During the Vårgårda fair, we received positive responses about our tool (most people responded "Very comfortable" or "Somewhat comfortable" to the idea of the car asking them questions). This reassured us that our concept would be valuable both for the researchers at the company and to the participants who are performing the test in the car.

Because the feedback that we received during the fair was generally positive, we decided that in the third iteration we would improve the concept of our tool and make it closer to the real thing, so we decided to:

- **P3.1** - implement our questions in LIV.

5.3.2 Suggestion

S3.1 - In order to achieve **P3.1**, our idea was that whenever a test participant would access a feature, the system would explain what the purpose of the feature is and then allow the participant to test the feature. Once they exited the feature, the car would ask them a question about how they felt about said feature and mention that they should press the recording button on the screen so their answer can be recorded.

During this iteration, we also had the opportunity to participate in the 40th edition of ICSE (International Conference on Software Engineering), which was valuable to us because it gave us the opportunity to allow the participants of the conference to test our concept and provide us with feedback. It also allowed us to gather more data and requirements to provide to Veoneer. During the usability tests at the conference, we wanted to allow the participants to be by themselves and allow them to only interact with the car. However, we decided that one of us should accompany the participants in order to be able to observe the test and also to intervene in case the participant needed help at some point during the test.

5.3.3 Development

To develop the tool in this iteration, we used NodeRED to inject our tool's messages. This way, the tool could talk to LIV and send and receive messages. Therefore, we implemented the injected messages at the time when we wanted them to pop up in LIV. In addition, we developed a process to save the received messages back from LIV into log files.

Using NodeRED, we managed to inject short explanations of the features of LIV that we wanted the participants to try out during the conference. Therefore, we first selected the features that we thought would be most valuable to present both for us and for the participants. Then, for each feature we injected a message containing a short explanation that would be spoken once said "feature was accessed" and a message containing a question related to how the participants felt about the feature once the participant closed said feature.

We also attempted to use LIV's integrated microphone in order to record the questions and the participants' answers and save them in a log file for further analysis. However, because of some issues with the microphone, we decided to use an audio recorder in order to store the participants' answers instead.

The second solution was necessary to be added because after conducting a pilot test of the tool with an employee in the company, we noticed that LIV had issues in understanding their dialect and some of the words that the employee said. Furthermore, since the speech functionality in LIV is trained to reply to the driver, it would interpret everything as a command and interrupt if it couldn't understand.

Because all of the messages that we introduced were hard-coded, we decided that one of us should be available in the car during the test. This is because we wanted our participants to follow a certain order of accessing the features. This is so we could make sure that the participants both had a chance to listen to LIV's instructions (such as "put on your seat-belt") and a chance to test all of the features before LIV asked them the final general question about new features that they had in mind. In addition, we wanted to provide the participants with a more in-depth explanation of what each feature does and why it is important.

Like in the second iteration, we prepared questionnaires to fill in by the participants after each test. These questionnaires were used in order to understand how they feel about our requirements elicitation tool and LIV's speech. We also included demographic questions (gender, age, and driving experience) in the questionnaire because we thought that that would help us to discover some patterns during the data analysis. The questionnaire was distributed after each test, either in the car or outside, and we were available to answer any unclear question in the questionnaire. The questionnaire can be found in Appendix 9.

5.3.4 Evaluation

Our approach was evaluated both by the participants of the conference through the questionnaire and by two employees at Veoneer. It is important to keep in mind, however, that due to the nature of this event, all of the participants have the same or very similar background and technical knowledge. This might introduce some bias in our results.

The ICSE evaluation can be seen in Figure 5.13. The response that we received for our tool was generally positive, with 69% of the participants saying that they either agree or strongly agree to our tool. In addition, participants suggested improvements such as:

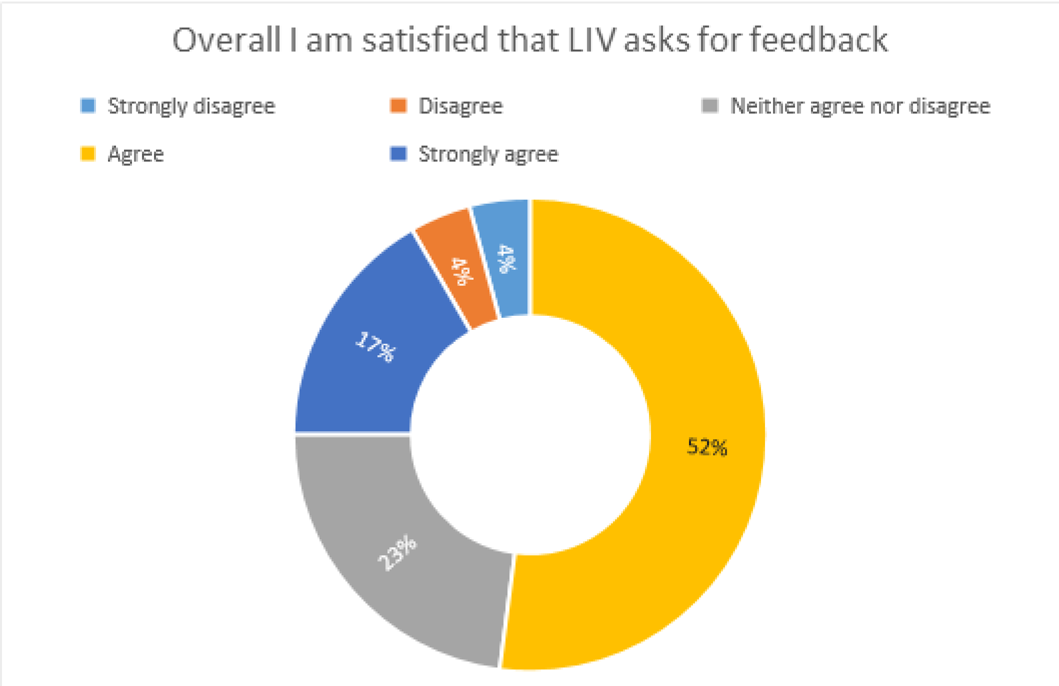

Figure 5.13: Feedback gathered during ICSE regarding the tool.

a. Changing the wording between the questions, so the driver feels that the tool is more natural.

b. Making the questions pop up randomly, not after each feature.

c. Adding the option to change the voice of the machine which asks the questions.

d. Ensuring that the tool is not too intrusive, i.e. does not ask for feedback all the time.

e. Adding the option to make the driver able to stop the questioning.

We also received generally positive feedback from the employees at Veoneer who tested the tool. However, they suggested the following improvements:

a. Changing the wording of the questions and the information LIV provides so they don't sound redundant (for example, in this iteration, most features contained the question "Do you like Feature X and why?").

b. Not stating the fact that a feature was closed (which LIV did in this version), because the participants can see that the feature was closed and they don't need "a cake on top of a cake".

5.3.5 Conclusion

The positive feedback that we received from the test participants serves as an assurance that this tool would be valuable for eliciting requirements in the future. However, our tool needs a few more additional improvements. One important upgrade was suggested by one of the Veoneer employees who had the opportunity to go through our test. They said that what they would want in the future is for our tool to walk the participants through an actual scenario and provide more in-depth explanations.

6
Results and Discussions

In this chapter we present the results and discussion of our research.

6.1 Results

At the beginning of our study, we set out to answer the following three research questions:

RQ1: What are problems of requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

RQ2: What are potential solutions to conduct requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

RQ3: To what extent can potential solutions address the problems of requirements elicitation for intelligent and interactive systems in the autonomous systems domain?

To answer these questions, we followed a Design Science Research (DSR) approach. We performed three iterations, and each iteration started with the *Awareness of the problem* phase, where we aimed to discover what the next steps are for improving our approach. Then, based on what we had found, we *suggested* what our next steps would be. Later, we *developed* our model and tool according to the suggestions. Then we *evaluated* our results. We were very lucky to be able to present LIV and prototypes of our tool in both the Vårgårda fair (during the second iteration) and the International Conference on Software Engineering (ICSE) (third iteration). Both the fair and the conference were valuable to us, because we received feedback from more than 80 end users, which made us feel confident about the conclusions that we drew. Finally, after the evaluation, we *concluded* our iteration by summarizing what we had accomplished during the iteration and deciding on what the appropriate next step is, i.e. planned for the upcoming iteration.

Our results, which can be found below, represent our findings related to our research questions.

6.1.1 Research question 1

We discovered the answer to this research question during the first iteration. As Table 5.2 shows, there is a number of issues within the area of requirements elicitation in the context of intelligent and interactive systems in autonomous cars. Out of all of these, we chose to focus on the following problems to answer the remaining research questions:

a. It is difficult to provide participants with a *natural experience* while driving.
b. There is not enough *data*. There is a need for both quantitative and qualitative data, and the data might be difficult to analyze.
c. There is a lack of *end-user involvement and diversity* among the participants that take part in the testing. The only people that get to test the concepts are company employees. This could introduce bias in the evaluation, since the test participants may be too involved in the project.

6.1.2 Research questions 2 & 3

To address the issues that we presented in 6.1.1, we came up with a concept for a requirements elicitation tool and a process model for innovative concepts.

A description of our tool and model, and why we believe they can help engineers elicit new requirements can be found in Sections 5.1.4.1 and 5.1.4.2.

During the second iteration, we managed to create a low fidelity prototype of the tool, which we later evaluated in the Vårgårda fair. A description of the prototype can be found in Section 5.2.3. At this fair, we also had the opportunity to ask the fair participants for feedback about our tool. We received positive feedback and the participants seemed to be open about a tool that is incorporated into the car asking them for feedback. However, we received some suggestions for improvements which can be found in Section 5.2.5.

During the second iteration, we also finalized the innovative concepts process model. We did this based on the feedback that we had received in the first iteration.

In the final iteration, we integrated the speech functionality of our tool in the car. More details about that can be found in Section 5.3.3. Later, we evaluated it in the ICSE conference. During the conference, we had the chance to ask the participants about the tool and the features in LIV.

Based on the feedback that we have received in iterations 2 and 3, we believe that our tool can help requirements engineers avoid the issues found in Iteration 1 in the following ways:

a. Using the tool would lead to a more natural environment for the test participants, because it removes the need for having the requirements engineer in the car to observe the driver.

b. Using the model, the issue of not including users during the design of innovative concepts is avoided. This is because the model allows practitioners to come up with new ideas by themselves while still being allowed to include users once they have a first prototype. This way, practitioners can receive feedback on what they have so far from users and modify the prototype accordingly. This ensures that the final product is something that end-users will enjoy and use.

6.2 Discussion

When coming up with an approach to address the issues that researchers and requirements engineers are facing in the elicitation process for intelligent and interactive systems in autonomous cars, we made sure that our approach would address their issues, and also the guidelines and/or issues encountered in the literature. We decided that it is essential to have an approach where users are involved in the process early on. This is because most of the papers that we read about requirements elicitation, i.e. Berkovich et al.'s paper [25] and Gould and Lewis' paper [31], highlight the importance of both including users [31], and also being careful not to include stakeholders that are irrelevant to the system [25]. In our research, we tried to accomplish what these two papers highlight by developing a model that includes users as soon as the development team has a first prototype. However, in addition to what Berkovich said about stakeholders, we also believe that it is essential to ensure that requirements engineers include a population that is as diverse as possible in order to make sure that we take into consideration the needs of as many user groups as possible.

In addition, because the tool that we have come up with would be used in the automotive industry in the context of autonomous cars, we believe, as Knauss et al. also mention in their paper [29], that it is imperative that the tool will take the environment and situations that the car and test participants are in into consideration. In other words, it will take information from the *context* that it is in. Because of this, we believe that our approach would work best if it took into consideration the conditions and situations that both the car and the participant find themselves in, and if the tool asked questions in certain specific situations.

We also chose to combine various requirements elicitation techniques in our process, in both the process model and tool, because we agree with Jiang et al. [26] and Mishra et al. [27], that a combination of requirements elicitation techniques leads to more complete requirements than using a single technique. Therefore, our tool combines the use of a prototype and a usability test in order to elicit requirements. However, we believe that the most important one is the prototype. This is due to the fact that, as our interviewees said during the interviews that we conducted, it is very difficult for users to understand what you are developing unless you show them some version of what you have right now. Thus, having a prototype is essential in the elicitation process for innovative concepts.

We also believe that extracting requirements in real-time would lead to clearer requirements and would eliminate the misunderstandings that occur between requirements engineers and various stakeholders . This is why when we started brainstorming how our tool should behave, we used Gall et al.'s [30] proposed framework as a starting point. The main difference between the mentioned paper and our tool is that our tool elicits requirements in an interactive way, i.e. by asking questions and saving the participants' answers.

Finally, as far as the model is concerned, we believe that Trimi et al.'s [34] and Eric Ries' [35] Minimum Viable Product (MVP) was a good starting point in the development of our model, since, much like their process model, ours is also based on generating ideas, evaluating and learning from them, and later on generating ideas again. The main difference between our model and their model is that we introduce the prototype as an essential part of concept development in our model. In addition, our model is very heavily focused on involving users as soon as you have a tangible artifact to test on them. What would have been very interesting and can serve as future research is drawing a comparison between our process model and the User-Centered Design process model and to see where they differ and where they are similar.

6.2.1 Contributions

We believe that our approach brings several contributions to both research and academia. The main contribution is that we provide a concept for a tool that makes use of a car's sensors in order to understand the context that a user is in. In addition, our tool removes the need for having a requirements engineer by the driver's side in the car. We believe this is valuable, because this will lead to more natural reactions from the driver. Furthermore, not having to be in the car all of the time would save time for the requirements engineers. Finally, the process model for innovative concepts that we proposed enables requirements engineers, designers, and researchers to involve users in their study at the right time (i.e. as soon as they have a prototype).

All in all, we believe that the results that we managed to gather so far provide a good contribution both to research and our company because our approach blends in real-time and contextual requirements elicitation, and a process model for innovative concept design and user involvement. As always, there is always room for improvement, and an additional iteration would have been valuable for us, but that is discussed further in Section 7.2.

6.3 Threats to Validity

This section describes the threats to validity in our project based on Runeson et al.'s classification [56].

6.3.1 Internal Validity

The selection of the interviewees in the first iteration was based on their experience in the automotive domain. Some of the experiences, however, were not in the requirements engineering domain, which creates a risk of them being irrelevant to our study.

In the interviews in the second iteration, the goal was to enhance the model and the tool implementation. The selection of the interviewees was based on the participants' long experience in the automotive domain. The risk in the selection was the lack of technical experience which resulted in participants not being able to answer a part of the questions. To mitigate this risk, we interviewed technical people in a second round to answer the technical questions.

Finally, one bias that we encountered is the fact that at ICSE, most (if not all) of our participants had a background in software engineering. We believe that this should be mitigated by reaching out to a more diverse population from a professional background point of view.

6.3.2 External Validity

We conducted our approach in one automotive safety supplier company, which has a research platform for an interactive and intelligent system. As Autoliv and Veoneer are big suppliers and have experience with many OEMs, we believe that in order to generalize the approach we have to replicate the project setup in exactly the same way in different other automotive companies. In order to demonstrate the ability in replicating the approach, we must provide statistical evidence that shows our results can be used to forecast outcomes in different experiments, which we were not able to do in this project due to time constrains. Therefore, this has been scheduled for further future work.

6.3.3 Construct Validity

In order to avoid a threat to the construct validity in misinterpreting our questions in the interviews in the first two iterations, we sent the purpose of the study and the goal of the interviews to each interviewee prior to each interview in both iterations. However, we could not ensure that the interviewees read or understood all terms and information in the email. To mitigate that risk, we started the interviews with an explanation of the thesis and the interview purposes and made sure that all of interviewees had the same interpretation of terms (requirements, elicitation, personas, etc.).

Additionally, we did a pilot test before each interview, to help us fine-tune the questions and reduce the number of unanticipated problems which may cause misunderstandings or misinterpretations of the questions.

In the questionnaires that we conducted during the second and third iterations, we mitigated the risk of misinterpreting the questions by being on-site and close to the participants to explain the questions - when needed - without interfering with their answers.

In the questionnaire that we administered to participants during ICSE, there was a mistake in one of the research questions, i.e. there was an answer option that was not supposed to be there. Unfortunately, we noticed that rather late in the conference and some participants had already selected that option. To mitigate this and avoid invalid data, we decided to eliminate that option and the responses that contained that option from our study.

Another validity threat that we encountered is the fact that some of the questions that we asked in the questionnaires were might be biased (e.g. "Do you feel comfortable that LIV asks for feedback"). We mitigated this by not relying entirely on the answers that were given to the questions, but also by listening to recordings and asking the question again in a different way during ICSE.

7

Conclusions and Future Work

7.1 Conclusion

The aim of this thesis was to investigate the challenges in eliciting requirements for intelligent and interactive systems in autonomous cars and come up with a requirements elicitation approach that represents a solution to those challenges, since there is neither enough research about how this is achieved nor enough evidence to suggest that traditional requirements elicitation techniques work for these types of systems.

To achieve what we set out to do, we used Design Science Research (DSR). We believed that this would be the most appropriate methodology for us since it allowed us to work in iterations and each iteration allowed us to produce an artifact which we could evaluate and decide how to proceed based on said evaluation.

We performed three iterations. The first one focused on discovering what the issues with requirements elicitation are with respect to the interactive and intelligent systems in the automotive industry and developing a solution to them. The solution that we thought about consisted of a model process for innovative concepts and a tool that would aid requirements engineers in eliciting requirements.

The model consists of several activities. It starts by coming up with an idea for an innovative concept, then you would generate knowledge, i.e. what is required in order to accomplish the idea. The following step is to look into the details of what is required in order to build the idea, after which you would build your first prototype. Once you have a first prototype it is time to involve users in the concept development process. This is because while users would not be able to give feedback on something that they have never seen before, they would be able to do it if they saw a prototype. After receiving and analyzing the feedback from the participants, the next steps are to analyze the data that you have collected, and then to collect new requirements or updates based on the feedback and to modify your prototype.

We aimed for out tool to support the definition of personas, which would help engineers in selecting a test population that is diverse and complete. The tool also aims to ask for feedback during a usability test using questions that had already been inputted by requirements engineers. This is so the participants could be in the car by themselves during a test, which would lead to a more natural setting.

The second and third iterations consisted of updating the model according to literature reviews, the feedback that we received from our supervisors, and the employees at Veoneer whom we interviewed. We also had the opportunity to participate in the Vårgårda fair and the International Conference on Software Engineering (ICSE), where we had the chance to test our approach with people outside of the company. Participating in these two events turned out to be valuable for us, because we managed to collect a high number of data points (more than 80). In addition, the feedback that we received from the participants, and the requirements that we managed to gather afterwards, made us feel confident that our tool is something that would be valuable in the future both for our company, and from a research perspective.

In iteration 3, the tool was closest to what we initially wanted from it (it would explain a feature once the test participant accessed it and ask a feedback question once the participant closed the feature). The positive feedback that we received made us see that it would be worth continuing to work further and improve our tool.

Finally, by the end of this thesis, we managed to come up with answers to the three research questions that we asked in the beginning. For *research question 1*, the answers were mostly gathered from the first iteration, while the answers to *research questions 2 and 3* were discovered throughout iterations 2 and 3. More details about the answers to our research questions can be found in Section 6.1.

7.1.1 Significance of the study

The findings of our study have both academic and industrial contributions. In the academia field, the thesis addresses problems and challenges that we have identified from previous research and experts in the company. In addition, we propose a new requirements elicitation approach for interactive and intelligent systems for autonomous vehicles. Additionally, the thesis explores the possibilities and the limitations of the designed approach, and provides suggestions for additional features and improvements on the approach in the future.

From an industrial point of view, Veoneer has been provided with a list of requirements and feedback from actual end users regarding LIV.

7.2 Future work

There are several improvements that could be made both to our model and our tool.

For our tool, the most important improvement would be to make it use the sensors that exist in cars and ask questions under certain driving conditions or situations as well (for example, if it is raining, the tool could ask one specific question related to that situation). This is important because some of the feedback that we receive from our test participants might depend greatly on the context they are in (for example, weather conditions or whether or not the car is in traffic or standing still, etc.). This improvement would also allow researchers or requirements engineers to ask more precise and insightful questions instead of question like: "Did you like this feature?".

Another improvement that could be made to our tool is that we could use an improved speech-to-text algorithm in order to store the responses of the participants. In addition, an interesting update to our approach would be to allow our tool to actually walk the test participants through a real scenario, e.g. asking the participants to take their hands off the wheel and saying that the car is now going into autonomous driving.

Moreover, it would be interesting is to explore how our tool should behave in a test when the car is moving. It would also be interesting to investigate how test participants respond to our tool in such a situation and if there is any significant difference between their approval of our tool in a driving setup and a "standing still" setup.

During the second iteration, we planned for the personas and a way to collect characteristics for multiple users. For that, we decided to build a web app that collects characteristics from different users, and saves the data in a database for later use. The saved data can be used in the search feature in the web app for personas that fit a specific project, or it can be used in other tools to automatically generate personas. It mainly includes three pages: the first page is a form to be fulfilled by the users' characteristics - the data in the form can be, for example, gender, height, driving experience, driving licence, etc. and it can be collected through interviews and literature. On the second page, one can view the data which was added by the users, and the last one is for the admin or the expert to connect projects with characteristics. However, the time to work on this was limited due to the preparation for the Vårgårda fair which took more than expected. Because we did not have the opportunity to evaluate our concept, we decided to postpone working with the personas and focus on the feedback-gathering aspect of the tool instead.

Nevertheless, we strongly believe that the persona functionality of the tool would be very useful to develop. We think that, in order to develop a product that people will want to buy and will enjoy using, it is crucial to involve them in the concept development process in order to understand what they really want and expect from a system. We believe that a list of personas would ensure that the researchers include a diverse and thorough test population.

As far as the model is concerned, as we were advised by one employee at Veoneer, we believe that it would be very valuable to our model to draw a comparison between it and the User-Centered Design process and see how they compare, i.e. what differences and similarities there are between the two of them and what different advantages both of these processes bring to the table.

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A

Appendix 1 - Iteration 1 Interviews

The questions of the first iteration, and the which research question RQ of the three research question they will answer:

- What do you do at AutoLiv (title and job description)?.
- What type of products have you developed while working here?
- Elicitation requirement is the practice of collecting the requirements of a system from users. When eliciting requirements, what type of requirements do you usually focus on? (i.e. technical, HMI-related, etc.) RQ1
- When eliciting requirements, which type of data (quantitative or qualitative) do you aim for? RQ1
- Which types of requirement elicitation techniques do you use for intelligent and interactive systems?
  - Why do you use this elicitation method in particular (how do you choose it)?
  - When in the development process do you use this method? RQ1 RQ2
  - If the elicitation method involves participants: RQ2
    - Who are the participants? RQ2
    - How do you choose the participants? RQ2
    - Do you use personas?How are they created? RQ2
    - Do you usually elicit requirements individually or discuss the process with a team? RQ2
  - Do you usually elicit requirements individually or discuss the process with a team? RQ2
  - Have you found any issues with this elicitation method? ex: the participants do not know what their needs are from a system, system is totally new and the users do not have any clue about it so they can't even imagine what they want etc.? RQ1
  - How did you overcome these issues? RQ2
- What issues did you face during elicitation requirement process in the automotive systems in general?
- How do you solve these issues and problems you faced in eliciting the requirements in the automotive systems in general? RQ2
- How do you check that the proposed solutions solve the issues? RQ3
- What elicitation techniques do you avoid due to problems and challenges? RQ1

The result of the interview analysis is shown in Figure A.1.

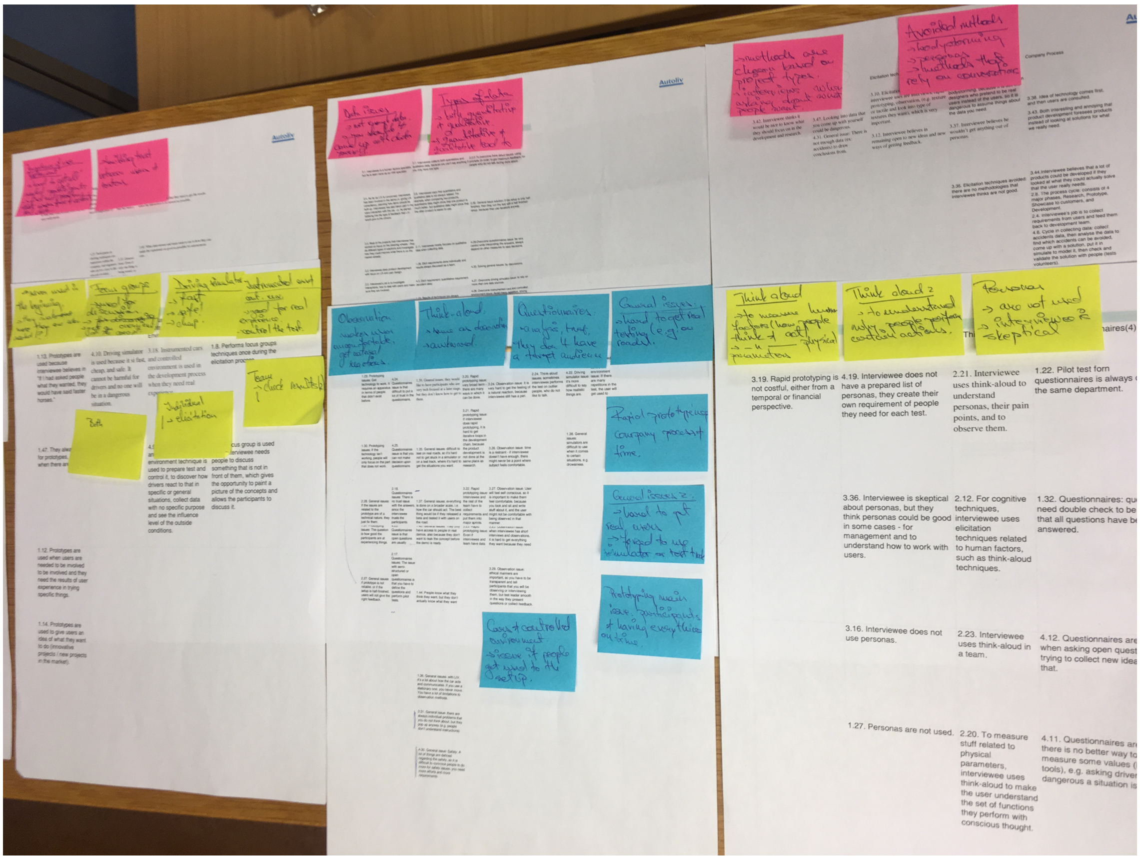


Figure A.1: The summary of the most important themes that emerged during the content analysis.

B

Appendix 2 - Iteration 2 Interviews

The questions of the second iteration, where we aimed to discover what the researchers and engineers from Autoliv/Veoneer would want our tool and model to look like.

- What do you do at AutoLiv (title and job description)?.
- What type of products have you developed while working here?

Questions about the model

- Do you think that following this model would be feasible for innovative projects?
- What is the needed information?
- Which step should be extended?
- Are there any steps that should be included or removed from this model?

Questions about the tool

- Questions about the persona functionality
  - What do you focus on when you're testing on users (use your imagination if you don't test on users)? (e.g. age, gender, experience, etc.)
  - Are there any categories of people that you don't want to include?
- Questions about collecting data in its context
  - We need to capture reactions to certain situations (e.g. turning up/down the volume, speeding) and in certain conditions (rain, snow, etc.). How can we do that?
    - Is possible to get these answers from the car?
    - Would it be useful to use a camera to save the reactions of the driver while they are performing the test?
    - Do you have any other suggestion for capturing reactions?
- Should this tool be embedded in the car or a standalone tool?
- The output of the tool will be list of requirements and we want it to be prioritised. Do you have any way to prioritise requirements. If not, do you have any suggestions?

Questions about the fair

- Can you imagine a scenario for the tool to be used in the fair?
- Which sensors would add the most valuable feedback taking into consideration that the car will be unmovable?

C

Appendix 3 - The Vårgårda fair questionnaire

1- What is your age?

☐ Under 15 ☐ 16 – 24 ☐ 25 – 34 ☐ 34 – 44 ☐ 45 – 54 ☐ 55 – 64 ☐ Over 64

2- What is your gender?

☐ Female ☐ Male ☐ Other ☐ Don't want to say.

3- Experience with modern technology (e.g. touchscreens, smartphones, etc.):

☐ None ☐ Not much ☐ Lagom ☐ A lot

4- Do you have a driver's license?

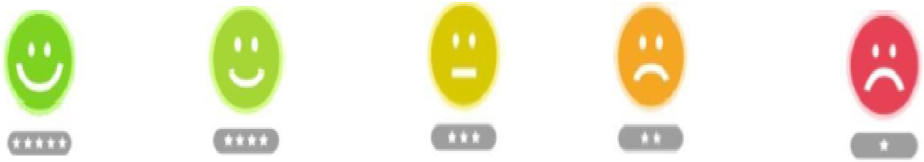
☐ Yes ☐ No

5- If yes, do you spend a lot of time in your car?

☐ Yes ☐ No

6- How likely are you to use LIV once it is on the market?

Very likely	Somewhat likely	Neutral	Somewhat unlikely	Very unlikely



☐	☐	☐	☐	☐

.

7- Would you take into consideration the warnings that LIV gives you, like “slippery road warning”?

Absolutely	Maybe	Neutral	Maybe not	Absolutely not
☐	☐	☐	☐	☐

8- Why?

9- Do you feel comfortable that the car talks to you for warnings, safety-related issues, while driving?

Completely comft	Somewhat comft	Neutral	Somewhat uncomft	Very uncomft
☐	☐	☐	☐	☐

10- Do you feel comfortable that the car talks to you while driving for social talk (yourself, music, situation,...)?

Completely comft	Somewhat comft	Neutral	Somewhat uncomft	Very uncomft
☐	☐	☐	☐	☐

11- Would you like to update any of the features?

12- Are there any features you do not like?

13- Can you imagine new features?

D

Appendix 4 - Ethics document

The ethics document that was given to each participant before the test.

veoneer Autoliv

During 20 and 21 of April 2018 in Vårgårdamässan, we are conducting a study to see how LIV, the “Learning Intelligent Vehicle”, should communicate with drivers. We want to test the way that LIV greets people and its functionality in order to see what people think about it and what they want from such a car. Your participation in the study will contribute to our research in creating a LIV concept that is not only safe, but users also enjoy. Should you change your mind about your participation in the test, you can stop it whenever you want.

During this test, we will record the actions that you perform using cameras and an audio-recorder. We will also be asking you a few questions related to LIV and we will be transcribing your answers. The data that we collect during this study shall be used by Veoneer for research purposes. In case you do not want your data to be kept, you should notify us and we shall remove it. In order to test the face recognition functionality of LIV, you will be required to register on the LIV mobile app with your name, e-mail, and a photo of yourself. This data will be saved in the cloud and deleted after the fair. No personal information will be stored.

By signing this document, you give your consent to all of the activities specified above. In case the participant is less than 15 years old, a guardian must sign for them.

Name: ____________________

Signature: ____________________

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Appendix 9 - The ICSE conference questionnaire

What is you age? *

- ◯ 18 -24
- ◯ 25-34
- ◯ 35 - 44
- ◯ 45 -54
- ◯ 55 - 64
- ◯ Over 64

What is your gender. *

- ◯ Female
- ◯ Male
- ◯ Other

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Do you have a driver's license? *

- ◯ Yes
- ◯ No

If yes, do you spend a lot of time driving? *

- ◯ Yes
- ◯ No

Do you think that the car speaks too much? *

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

Overall I am satisfied that LIV asks for feedback. *

- Overall I am satisfied with the system *
- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

Are there any features that you do not like in LIV?

- Yes
- No

If yes, what are the features?

Short answer text

Would you like to add new features to LIV?

Long answer text