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Concept Development of a User Interface for Remote Tank Monitoring of IBC Tanks

Master's thesis in Industrial Design Engineering

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Cover: Visualisation of a conceptual remote IBC tank monitoring system.

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Abstract

The process industry is being shifted through emerging technological advancements and digitization. This created an opportunity to develop a new remote tank monitoring and inventory management system for mobile plastic tanks, also known as IBC tanks. The main focus of this project was to identify and define user needs and requirements for developing a remote monitoring system for mobile plastic tanks. The user needs would be presented through the development of a theoretical framework for developing a digital monitoring system and a conceptual solution focusing on user experience and human factors.

The user needs were identified in the early stages of the project through interview studies, a workshop, benchmarking and opportunity identification. When the user needs and requirements were identified, they were analysed, redefined and mapped out through the analysis methodology and systems theory. The concept generation resulted in a configuration of hardware and software working together to create functionalities that filled the user needs. The hardware unit includes a set of electronic and user interface components that serves the purpose of feeding data to the software while keeping the unit complexity low. The software concept was a user interface design, built to facilitate remote tank monitoring, easy pairing, inventory analysis, inventory management and inventory security.

A digital prototype was made in the delivery phase of the project which resulted in a series of visualisations presenting the theoretical framework for developing a digital remote tank monitoring system, which was identified in the development phase.

Keywords: Industrial design engineering, user experience, systems theory, digital prototyping, remote tank monitoring, user research, UX/UI.

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Tom Krznar and Andrea Hansson, Gothenburg, June 2021

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List of Abbreviations

Throughout the report, terms are used which are common in the RTM (remote tank monitoring) and UX (user experience) industries, some of which have several definitions. This list describes individual meanings of the words which are in relation to the context of this report.

IBC	Intermediate bulk container
RTM	Remote tank monitoring
ROAC	Radar on a chip
GNSS	Global navigation satellite systems
UX	User experience
UI	User interface
HW	Hardware
GPS	Global positioning system
API	Application Programming Interface
KPI	Key performance indicator
RFID	Radio Frequency Identification
QR	Quick response
BLE	Bluetooth low energy
LED	light-emitting diode
ERP	Enterprise resource planning
3D	Three dimensional
SW	Software
IM	Inventory management

1

Introduction

Intermittent bulk containers, usually called IBC tanks (see Figure 1.1), are mobile plastic tanks that usually contain 1000 litres and are used to store liquids and solids in a wide variety of industries. The IBC tanks are used for collecting rain water, storing chemicals in the process industry and vegetable oils in the food processing industries, to mention a few use cases. The number of tanks used by a company can vary from a few to thousands. Radar technology is traditionally used to monitor levels in stationary tanks, but as radars become smaller and cheaper, the opportunity to connect them to cloud solutions has evolved. This enables tank monitoring also on mobile tanks. This thesis will research the customer and user needs around remote tank monitoring systems for IBC tanks and will be presented in a conceptual solution.

Figure 1.1: An empty IBC tank.

1.1 Background

More than 20 million intermediate bulk containers (IBC tanks, see Figure 1.1) are manufactured each year. They are made of plastic with a cage, usually made of metal, and sit on a pallet. IBC tanks are usually stackable and usually hold 1000 litres, but other volumes do occur. They are used for storing and shipping liquids and solids within a wide variety of industries, such as chemical, pharmaceutical, food and beverage, and water and wastewater industries.

Remote tank monitoring can be performed by a variety of technologies such as weight or ultrasonic, where the common denominator is that they measure the level of the content in a tank and communicate it to a remote user who utilizes the information. With the introduction of Radar on a chip (ROAC), radar units can be made smaller, cheaper and simpler compared to radar devices used for level monitoring on larger tanks. This opens up possibilities to utilize radar technology also on smaller tanks, such as IBC tanks. Fagerberg (2020) divides the infrastructure of remote tank monitoring in four parts: tank segment, localisation segment, network segment and backoffice segment (see Figure 1.2).

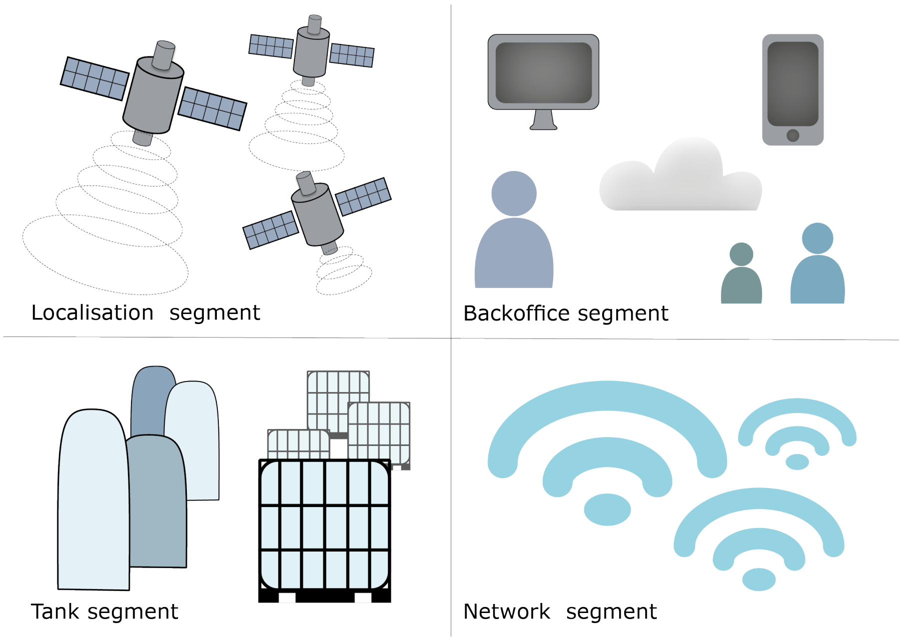

Figure 1.2: The infrastructure of the remote tank monitoring business sector.

Fagerberg (2020) sees logistics management as an application for remote tank monitoring systems. This includes level monitoring, location tracking, security tracking, regulatory compliance and health and safety monitoring. optimizing transportation routes when IBC tanks are being re-distributed or refilled is another application.

Some other possible applications of remote tank monitoring on IBC tanks have been identified to be measuring during filling to ensure recipes, tracking of inventory during storage, tracking and status checking of IBC tanks during transportation and non intrusive inventory checks (Fagerberg, 2020).

1.2 Aim

This project aims to identify and define user needs and requirements for developing a remote monitoring system for mobile plastic tanks. The user needs shall be presented in a conceptual solution focusing on user experience and human factors.

The aim will be reached by answering of the following research questions:

1. Who are the stakeholders for this project, in which industries do they work and what are their needs from remotely monitored IBC tanks?
2. What would a theoretical framework for developing a digital monitoring system based on human factors and user experience look like?
3. How could a conceptual solution based on the identified theoretical framework be visualised?

1.3 Limitations

This project is limited to conceptual development of the system that is required to preform remote tank monitoring in IBC tanks. The digital software concepts will not be developed to the point of functional interactivity, but will be limited to their visual appearance. The project will not regard the aspects of economics or monetisation of the system. No technical aspects of radar systems, sensor technology, or software development will be addressed.

1.4 Outline of the report

The content of the report is structured in the following chapters:

2. Theory	This chapter presents the theory on which this project rests on. The theory includes the design process used, systems thinking, user experience framework and human factors.
3. Methodology	In this chapter the methodology used is presented. The methodology chapter is divided into four chronological phases named discover, define, develop and deliver, where each phase has a specific goal to fulfil.
4. Result	Chapter four presents the results that came from the methodology used, and is divided into the same four phases which are also present in the methodology chapter.
5. Discussion	This chapter presents a discussion of the process and result that has come of this project.
6. Conclusion	In this chapter, conclusions are drawn and any presumed further work is presented.

2
Theoretical framework

This chapter addresses the theoretical aspects of this project and defines the scientific base it rests upon. The design process of the project is described in detail to show the workflow of the project. Systems thinking is described to show the way all aspects of the project was structured to be comprehensive. User experience and human factors is described to establish the science on how users and their needs are evaluated in the project.

2.1 Design process

The Double diamond design process (see Figure 2.1) was chosen as a design process for this project. The double diamond process is a framework consistent of two diamonds where the process in each diamond starts with divergent thinking and moves forward to convergent thinking (The Design Council, 2015a,b). The four stages of the process are called Discover, Develop, Define and Deliver.

In the first divergent discovery phase design research takes place, and moves over to the convergent definition phase as the results from discovery are transferred into creativity processes and idea generation (The Design Council, 2015a). As the definition phase ends The Design Council (2015a) means that the problem definition should be clear. In the next convergent phase of development ideas are reviewed and analysed and the process converges into the delivery phase with prototyping and selection of concept (The Design Council, 2015a).

The process will be iterative as the arrows in Figure 2.1 shows. As new insights will be reached, and the knowledge of the problem grows, the process might have to be restarted (The Design Council, 2015b).

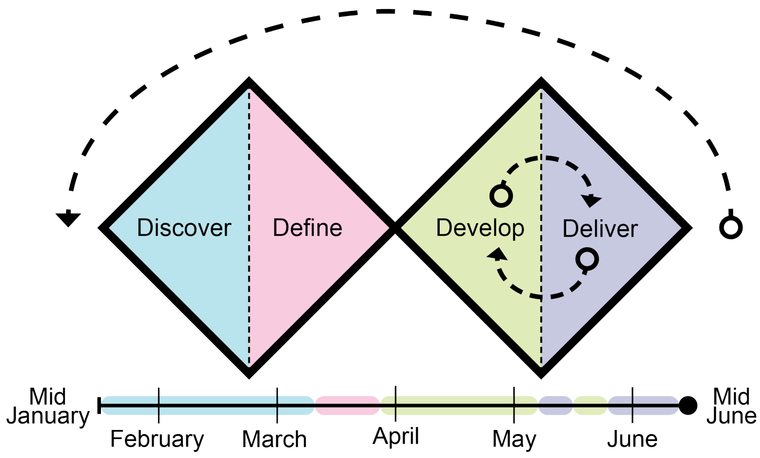

Figure 2.1: The Double Diamond design process and a timeline of the project.

The reasoning behind the choice of the double diamond process was that it would wold work well with the available time and resources. In the selected research and development process, only one of the two diamond segments can take a flexible amount of time for it's execution. As the second diamond is iterative, and the duration can be shortened or lengthened depending on time and resources available. This gives a useful degree of flexibility.

As the first diamonds served as a research foundation, the second represented the presentation of a conceptual solution which was based on the gathered research in the first diamond. Priority was placed on having a higher quality of user studies in comparison to concept development. That meant that if this process was utilised, the research part would have enough time in order to achieve the expected results, and the conceptual solution would reach the quality level which was based on the time that remained.

The Five Stage Design Thinking Model (see figure 2.2) by Plattner et al. (2012) was also considered useful. It had the same phases As The Double Diamond process, but the testing phase is its own phase and the discover phase is called emphatise. In the Double Diamond process, testing is done in the delivery phase. This process was not chosen, because it does not allow enough flexibility, and included iterations that were not planned. Although iteration is proven to produce quality results, it would take too much time.

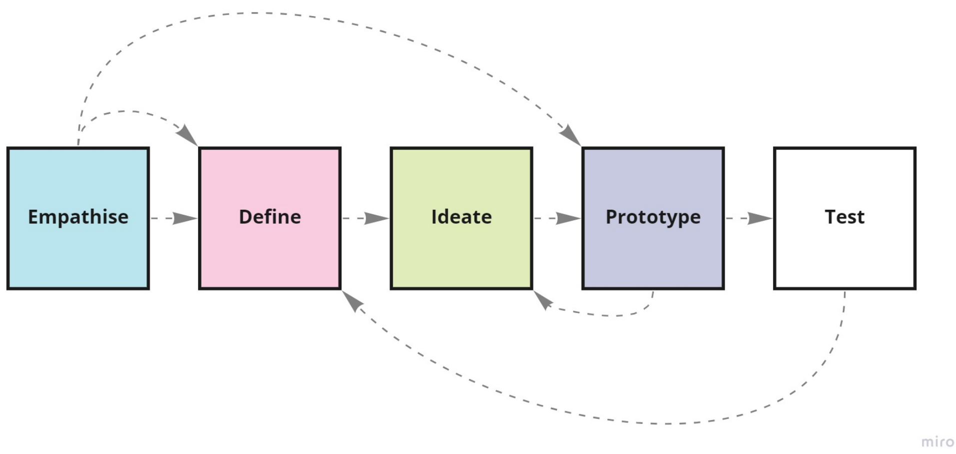

Figure 2.2: The five stage design thinking model.

2.2 Systems thinking

Systems thinking is a subcategory of systems theory, that has existed for many decades and is an interdisciplinary study of systems Checkland (1999). The term could be described as organised thinking. There are many definitions of what systems thinking, but the definition of Arnold and Wade (2015) illustrates the reasoning and benefits of using it. Their definition is that systems thinking is the ability to think abstractly in order to:

- Incorporate multiple perspectives.
- work within a space where the boundary or scope of problem or system may be undefined.
- Understand diverse operational contexts of the system.
- Identify interrelationships and dependencies.
- Understand complex system behaviour.
- Reliably predict the impact of change to the system.

This definition illustrates systems thinking as a skill set for depth understanding of complex behaviours and how they can impact an ultimate outcome. A famous quote could be used set an example to how systems thinking could be viewed from an untrained perspective:

"If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions."

-Albert Einstein

This quote illustrates the importance and superiority of examination and preparation in comparison to action. The application of systems thinking is becoming increasingly more common (Basadur et al., 2000). There are many reasons for that, but the most obvious one is that world itself is becoming increasingly more complex. Problems which never existed to this point in history are arising exponentially making the standard ways of approaching them obsolete. This created a need for searching for new problem solving approaches which systems thinking often finds a way to.

2.3 User Experience Framework

Rosenzweig (2015) describes User Experience (UX) trough usability. A system is usable when it provides an useful service to an individual and that human centred design puts technology into useful tools. That gives individuals the potential to reach their goals trough good UX.

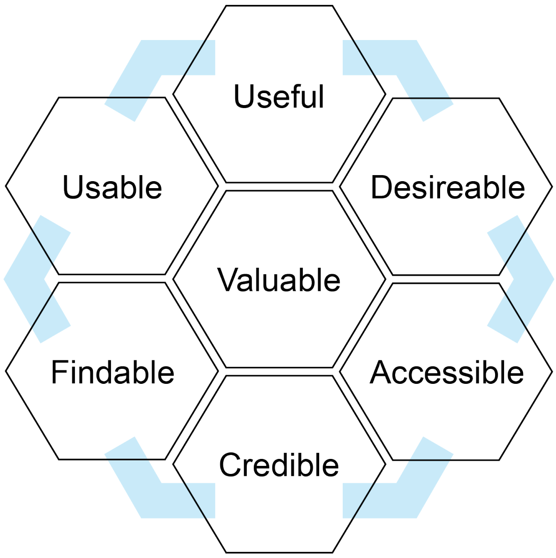

Figure 2.3: The UX honeycomb model.

The UX honeycomb (see Figure 2.3) was created by Peter Morville with the purpose of explaining user experience (Knight, 2019). Each piece in the honeycomb represents a part of the user experience, and the keywords for this are useful, usable, desireable, findable, accessible, credible and valuable. These concepts are described by Knight (2019) as:

Useful: The product must solve a problem or fill a need for the user, or it quickly will be redundant. You must know the user and their behaviour to stay relevant to them.

Usable: It is important that a product is easy to learn how to use as well as it should be easy to use. This is key to retain customers.

Desirable The emotional connection to a brand or product often have impact on the user experience, and a product should contain elements that evoke these emotions.

Findable: The user must be able to find what they need to fulfil the purpose of use.

Accessible: A product should be usable by everyone, despite any physical or cognitive impairments.

Credible: The user must be able to believe what the product tells them.

Valuable: The product must deliver value to the satisfaction of all stakeholders, from user to business.

User experience can be integrated to the design process by using the UX framework (Watanabe and Shirasaka, 2021). The UX framework is used by keeping track of stakeholders requirements and turning them into system requirements. User experience design is a principle that involves multiple disciplines of design. According to Knight (2019) these disciplines are user research, content strategy, information architecture, interaction design, visual design and usability evaluation. The purpose of involving each discipline is described by Knight (2019) as:

User research User research should be preformed to understand the needs and behaviours of potential users to make an interpretation on the effect a design has on them.

Content strategy This aims to make sure that the contents of the product are meaningful an engaging to the user.

Information architecture This is a discipline that aims to help the user understand where they are, where they have been and what to expect next when they navigate trough the information shown to them. This is achieved by making the relation of content understandable, organising them in a logical and meaningful way to the user.

Interaction design Interaction design is a field that strives to design interfaces that are meaningful and engaging to the user. This is done by trying to understand how the user interacts with technology and then design interfaces that are intuitive, mitigates errors and gives feedback on the users action.

Visual design Visual design enhances the user experience and builds trust in the brand by using visual elements to present a message.

Usability evaluation This is used to measure the experience of the users interaction with a product interface. Methods are used to measure intuitiveness, error frequency, learnability and subjective satisfaction.

2.4 Human factors

Ergonomics is seen as the knowledge of the human abilities, limitations and characteristics that affects the design of artefacts, systems or environments, to make these effective, safe and comfortable for humans to use (Hollnagel, 1997). Human factors, also called Cognitive ergonomics, are the mental aspects of ergonomics and regards how these designs affects the mind, and how the mind affect designs (Hollnagel, 1997). Cognitive ergonomics can also be referred to as human factors engineering.

Human performance is recognised as a contributor to major accidents, specifically in the oil and gas industries. It has been concluded that human and organisational factors such as the design of equipment interfaces and work environment have contribute to loss of human reliability leading up to accidents (McLeod, 2015).

2.4.1 Visual perception

The perceptual organisation of visual elements is an important factor in the design of visual displays (Proctor and Proctor, 2012). The concept of prägnanz stems from gestalt psychology, first mentioned by Köhler (1920) and later refined from the experiments by Wertheimer (1923). They suggest objects perceived will be organised the simplest way possible. A display that is viewed will be perceived as a background with figures and either the darker or lighter of the elements will be seen as background.

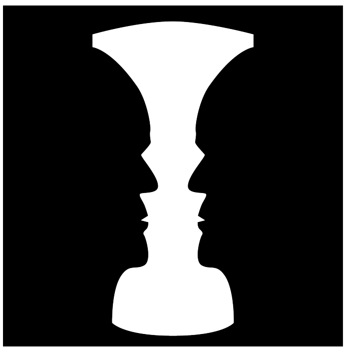

Figure 2.4: The Rubin's vase.

This was first described by Rubin (1915), now known as The Rubin's Vase (see Figure 2.4). This shows how symmetrical patterns will be perceived as a figure and a figure that completely surrounds another figure, will be perceived as a background. Grouping of elements (see Figure 2.5) is another important factor in how objects are perceived, and according to Proctor and Proctor (2012), the most recognised ones are:

Proximity	Objects close to eachother tend to be grouped together.
Similarity	Objects of similar shape or color tent to be grouped together.
Continuity	Figures tend to be organized in continuous paths.

Closure	Elements that make up a closed figure usually get grouped together.
Common region	Objects that are collected within a border tend to be grouped together.
Connectedness	Objects that are connected with a line tend to be groped together and separated from other connected groups.

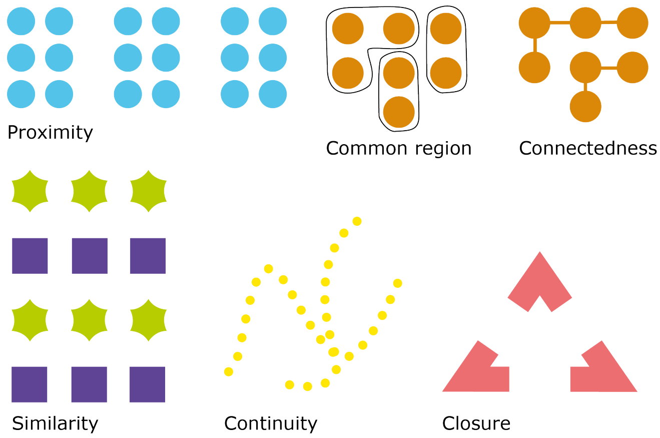

Figure 2.5: The gestalt laws.

The principals of proximity, similarity, continuity and closure (see Figure 2.5) were introduced by Wertheimer (1923) and the principals of common region and connectedness were presented by Rock and Palmer (1990). Palmer (1992) demonstrated that when several common regions are are conflicting, the smallest one dominates the grouping. When regions are nested and consistent, they are perceived hierarchical.

2.5 Stakeholder management

The stakeholder classification model presented by Mitchell et al. (1997) is a venn diagram (see Figure 2.6) where the level of stakeholder power, legitimacy and urgency defines the attributes of a stakeholder. Stakeholder power indicates to what degree a stakeholder has the coercive, utilitarian or normative means to get their will trough (Mitchell et al., 1997). Power should be seen as transitional, as it can be gain or lost.

The definition of legitimacy by Mitchell et al. (1997) is somewhat vague but implies that most scholars defines it as a normative trait. It could be found in moral claims, something at risk or other constructs and is seen as a larger cause or a social greater good(Mitchell et al., 1997). To have urgency as a stakholder, Mitchell et al. (1997) means that there must be both a critical time factor and a great importance or critical aspect for the stakeholder. Mitchell et al. (1997) states possible critical factors can be related to aspects of ownership, sentiment, expectation and exposure.

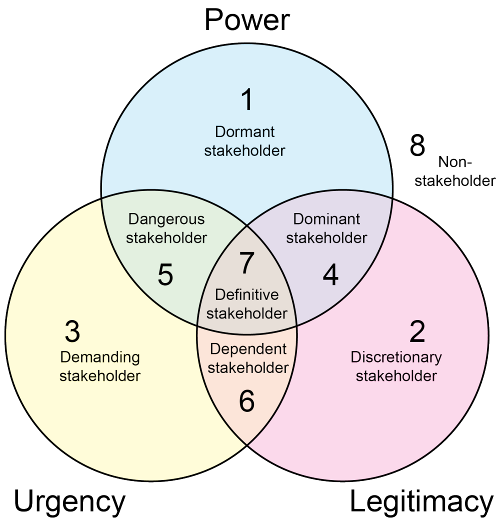

Figure 2.6: The stakeholder classification model according to Mitchell et al. (1997)

When these attributes are put into the model, each field in the diagram creates a classification that have different attributes, needs and claims. These classifications are describes by Mitchell et al. (1997) as follows:

1. **Dormant stakeholder:** These stakholders have power over a company, but no reason to use it.
2. **Discretionary stakeholder:** There is legitimacy to the claim of a discretionary stakeholder, but no power or urgency to influence a company.
3. **Demanding stakeholder:** By not having power or legitimacy to their claim, demanding stakeholders mostly search for attention.
4. **Dominant stakeholder:** With the combination of power and legitimacy, dominant stakeholders can influence a company and act on their claims.
5. **Dangerous stakeholder:** By having power and urgency a stakeholder can be coercive and force their illegitimate claims.
6. **Dependent stakeholder:** By lacking power, these stakeholders are dependent on the advocacy or governance of other, sometimes dominant, stakeholders to voice their claims.
7. **Definitive stakeholder:** By having all attributes, the dominant stakeholder will enjoy the priority and attention by managers.

8. **Non-stakeholder:** Someone claiming to be a stakeholder without having any attributes are not a stakeholder.

Salience is the level of attention of which managers give attention to a stakeholder claim. Mitchell et al. (1997) means that the level of salience depends on the number of attributes a stakeholder has, with more attributes giving higher salience. Classes 1-3 have low salience, and are seen as latent stakeholders (Mitchell et al., 1997), implying that they are dormant. Class 4-6 are seen as moderatly salient, expectant stakeholders, as they expect something from the situation they are stakeholders in Mitchell et al. (1997). Class 7 is the definitive stakeholder that has all attributes and therefor is a highly salient.

3
Methodology

The methodology chapter presents a set of design methods chosen based on their focus on innovation, user experience and human factors engineering. The methodology is divided into the four phases of the double diamond process (see Figure 2.1). The discover phase researches the market and users, the define phase methods define which findings should be taken forward, the develop phase generates and iterates the ideas and in the deliver phase the ideas are prototyped, tested and refined.

3.1 Discover

The discover phase aims to establish the context of the project. It includes methodology for studying the market, competitors, and users, in order to collect information that can reveal user needs.

3.1.1 KJ-analysis

KJ-analysis is a method for picking out user needs that are identified during the discover phase. Statements made by stakeholders are grouped by similarity, and deviant statements are placed on their own (Shun and Kosuke, 2010). When all results from the discover phase is reviewed all the identified needs are categorised and can be labelled appropriately.

KJ-analysis was used to sort and categorize statements from all user study activities related to the discover phase.

3.1.2 Benchmarking

Benchmarking is meant to study competitive solutions, solutions to similar problems and solutions to other problems that can be used to solve the problem of the current project (Ulrich and Eppinger, 2012). Using benchmarking will aim to research how competitive companies places themselves on the market, to possibly identify key features for a RTM solution, and to identify gaps in the market.

Benchmarking was preformed on the hardware of four competitive products that fill the need of level monitoring on IBC-tanks. Two software applications that work with the measurement device of corresponding company were also analysed. The needs from the requirements table were used as a guideline for finding relevant information, but some new possible needs were found and entered with the requirements.

Of the four competitive solutions, the ones from Endress & Hauser and Vega were established on the market. The ones from Packwise and Nanolike were on the market for testing with customers. From the two established solutions the technical data sheets were studied to find the functionalities, while the testing solutions did not share that data publicly, and only information from their websites could be analysed.

The software was analysed by finding screenshots from the companies websites and demo software, which were compiled into collages where different functions were highlighted. The results were put into its own part of the requirements table, see Appendix 1.

3.1.3 Identifying opportunities

Ulrich and Eppinger (2012) describes the practice of doing market research in order to find successful innovations that can be imitated to fulfil a different need, or refined to address the same need in a different context. This could be done by researching patents, looking trough media and marketing of companies in interesting business areas. The aim of doing research for identifying opportunities is to find solutions to sub-functions that emerge during the discovery phase.

3.1.4 Interview study

According to Kvale (2007), the quality of an interview study rests on the craftmanship of the researcher. Interview studies can be methodological or not, and this creates an openness where the decision of following a lead or the interview guide has to be made in the moment (Kvale, 2007). An interview study can according to Kvale (2007) be divided into the following seven steps:

1. **Thematizing** The purpose and theme of the study needs to be formulated. This represents the why and what of the study.
2. **Designing** The study needs to be planned and designed whit the aim of finding the intended knowledge. Moral implications of the study shall be taken into account.
3. **Intervewing** The interviews should be conducted based on an interview guide, and the researcher needs to have a reflective approach to the knowledge that is sought after.
4. **Transcribing** The interview material needs to be prepared for analysis by transcribing the interview from speech to text.
5. **Analyzing** The method of analysis needs to be chosen bases on the purpose and topic of the study and the nature of the interview material.

6. Verfying	The validity, consistency and possibility to generalise the results needs to be established in order to confirm that the study investigates what it supposed to.
7. Reporting	The method and findings of the study needs to be presented so that it lives up to scientific standards and takes ethical aspects into consideration.

When creating a interview guide Kvale (2007) means that it is beneficial to write two interview guides; one with the researchers questions, to specify what knowledge is sought after, and the interviewers questions, that aims to collect rich and varied answers. Kvale (2007) suggests the following types of questions can be useful an interview study:

Introductory questions	When the subject gets to open an interview by describing a situation from their own perspective, spontaneous and personal experiences can be uncovered.
Follow-up questions	By being curious, persistent and critical as an interviewer, the subject may elaborate their answers. This can be done by direct questions, agreeing, or leaving silence to invite for more elaboration.
Probing questions	Probing is a method encouraging the subject to tell more without specifying what dimensions of the answer is looked for.
Specifying questions	These types of questions are used to find precise statements where the answers are of a general kind.
Direct questions	In the later part of an interview, when the subject has shown what is relevant to them, direct questions can be asked to get specific answers on specific topics.
Indirect questions	To get a general view of attitudes of others or themselves, indirect questions can be asked, but needs to be followed up by questions that allows the answers to be properly interpreted.
Structuring questions	In order to break off long answers or steer the interview, structuring questions can be asked to lead the interview in the desired direction.
Interpreting questions	By rephrasing answers, clarification from the subject can leave new information to the interviewer.
Silence	By leaving silence in the interview, the subject is given the opportunity to reflect and break the silence with new information.

The interview guide (see Appendix C) was constructed to include as many types of questions as possible. Introductory questions were asked to establish the context of the industry and professional role of the interviewee. Probing and follow-up questions were spontaneously used to search for more information. Direct questions were used when there was an opportunity to get the interviewees opinion on a matter. Three sets of images of the prototype was used as a mediating object with the aim of starting a conversation on the user needs of their industry and to get feedback on the visual information presented in the prototype.

The case company had previously contacted possible users to learn about their industries, needs and restrictions in terms of tank monitoring on mobile tanks. There were five individuals interviewed, who were engineers and managed the instruments and technology upgrades in their facilities. The interview guide used had open questions that searched for similar knowledge to what was needed in the primary phase of user studies, so the material was deemed relevant to analyse for finding user needs.

Relevant statements from the interviews were analysed with KJ-analysis. Statements were sorted in to categories such as business model, connectivity, safety, measurement data, hardware and software. When the analysis was done, the statements were translated to needs and put into the requirements table (See Appendix A).

The interview guide were used for the second round of interviews, two individuals were interviewed. One worked the paint industry and one worked the food and beverage industry. Both worked in managerial roles. Statements from the interviews were noted and the relevant ones were written besides the image of the prototype it referred to. The feedback from the interviewees was subjectively analysed and put into the UX-honeycomb (see Section 2.3) to get a better overview of the user experience. The result was used as feedback for iterations in the prototyping process.

3.1.5 Workshop

A workshop is a knowledge sharing method where participants gather to explore a specific topic in a creative way. The purpose is to utilise the higher idea generation potential of a group, in comparison to that of an individual (Wikberg Nilsson et al., 2015).

A workshop was held in early stages of the discovery phase to expand existing knowledge base. The workshop included 12 participants and 1 facilitator. The participants were 11 engineers working with product and business development within the organisation of the case company and one industrial design engineering student. The area of exploration was large, and the aim was to get a better understanding about the vision of the case company, their existing knowledge and technological possibilities.

The workshop was held digitally through the communication platform Teams and digital whiteboard Mural. The workshop design was approached in a structured manner, including the following activities:

Introduction	Facilitators and participants introduced themselves and their professional backgrounds.
Context presentation	A presentation about the context and aims of the workshop was presented to the participants in order to establish and clarify the expectations.
Warm up exercise	A warm up exercise was held for the participants to get acquainted to Mural.
Ideation exercise 1	The first ideation exercise focused on a broad vision of business opportunities. This activity was executed in groups of four, so that the participants were able communicate but still not affect the diversity of ideas from other groups during 20 minutes.
Ideation exercise 2	The second ideation exercise was a session where technical functionalities were explored. The exercise was done individually, in silence, by all participant, during 20 minutes.
Voting session	The voting session included examining and rating of the ideas. The voting results was used as conversation starter for the discussion activity.
Discussion	The results from voting were discussed and details were further explained.

The result was analyse with KJ-analysis and put into the reqirements table.

3.2 Define

According to The Design Council (2015a) the define phase is where elaboration and filtering of data which was gathered in the discovery phase takes place. The define phase also aims to set a context to develop and delivery phases. In the context of this project it meant the definition of which data sets should be kept and which should be discarded. This was done through the use of defining product requirements and systems mapping.

3.2.1 Defining product requirements

The needs of users are usually expressed in the language of the user and are difficult to quantify (Ulrich and Eppinger, 2012). To make the user needs manageable they need to be translated into specifications, that shows what a solution need to do in a precise way (Ulrich and Eppinger, 2012). The requirement should not express how user needs are fulfilled, but rather what the solution needs to do in order to fulfil them.

According to Ulrich and Eppinger (2012), a list of metrics should be prepared from the identified user needs. The needs can be ranked based on the importance to the user. Benchmarking of competitive products can be done based on these metrics. When all information is compiled, it is be converted to ideally and marginally acceptable target values (Ulrich and Eppinger, 2012). The specification need to be evaluated during the development process and is finalised as technical and cost related details are specified

The needs found in the analysis of interviews and the workshop were used to benchmark competitive solutions. In order to decide the relative importance of each need, they were graded from 1-3, and the needs seen as a requirements were marked with a "R". A mean was calculated and.the needs that received a mean from 2,5 to 3 were chosen along with the requirements to be included in further prototyping.

3.2.2 Systems mapping

Systems mapping is an organisational tool which is based on systems theory and systems thinking (Lee et al., 2017). It is a holistic approach for examining complex, real-world systems. Systems mapping is useful when the amount of information in a system becomes too large to comprehend. A systems map becomes a visual aid and gives a holistic view of the system. System mapping was utilised in the define phase, in order to organize the technological parameters for the solution.

According to Lee et al. (2017) the fundamental principles of systems mapping are interconnection, adaptation and environment, that focus should not be directed towards individual components, but to the dynamic interrelationships between them. Interesting patterns and behaviourscan emerge from the interrelationships that otherwise could be missed. The process of creating a systems map is presented in figure 3.1. It shows the conversion process of an unorganised set of components into an organised system map. The process is done in the following four steps:

1. Compilation of all system components.
2. Sorting of components into categories based on similarities.
3. Defining which systems category the components fit into by creating category bounding boxes
4. Establishing interconnections between components with directional arrows

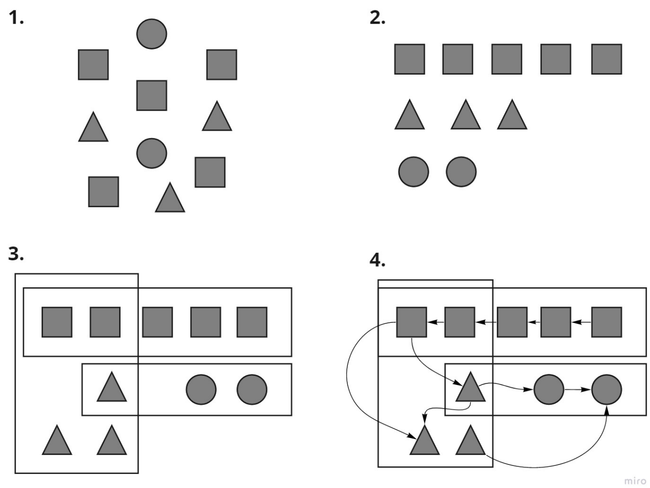

Figure 3.1: Systems mapping process.

The top row of Figure 3.2 represents a systems map scenario where a component is removed from a system that has defined interrelationships. The bottom row showd a system that do not have interconnections established. This suggests that mapping is more accurate when interrelationships are defined.

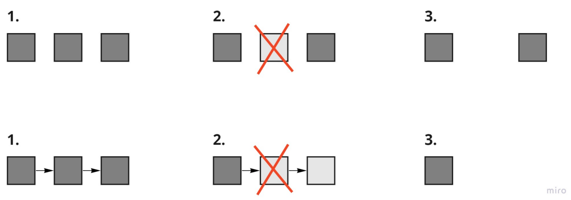

Figure 3.2: Interrelationship functionality in systems mapping.

3.3 Develop

In the develop phase the most promising ideas from the first diamond are selected, developed further and tested in an iterative process (see Figure 2.1) (The Design Council, 2015a). According to Kurt et al. (2017), creativity plays an increasingly crucial role for innovation in an organisation or a development project. Therefore, the primary development phase focus was concept generation.

3.3.1 Concept generation

Concept generation is a way of boosting confidence of a product development project, through the exploration of the full solution space (Ulrich and Eppinger, 2012). According to Ulrich and Eppinger (2012) This is done in the five following steps, that are designed to reduce the likelihood of having to make drastic changes in later stages of development.

1. Problem clarification:	The problem was broken down into subproblems and the focus was put on the most critical subproblems.
2. Search externally:	This was done through discussions with experts in the technological field, case company engineers and benchmarking information.
3. Search internally:	This step exploits the potential of personal input to the concept generation, by suspending personal judgement, generating many ideas, and welcome ideas that seem infeasible.
4. Explore systematically:	Systematical exploration was used by visualising data in diagrams based on systems thinking theory.
5. Reflect on the solutions:	The process and result was reflected upon, in order to identify any strengths or weaknesses that could be used for improvement.

3.4 Deliver

In the deliver phase concepts are prototyped, tested and evaluated in an iterative process (The Design Council, 2015b). This was done through user interface prototyping and usability testing which were chosen based on the results from the develop phase.

3.4.1 User interface prototyping

The method that was chosen for user interface prototyping has five steps that are suggested to be preformed in a sequence, but can also be adjusted to the context of a project and still provide good results (Shneiderman et al., 2016). The five steps are:

1. The first step defines use scenarios and conceptualises data flow diagrams of the user interface. The diagrams can be tested with users.

2. The second step contains the visualisation of data flow diagrams and identification of primary components and their interrelationships.

3. In the third step, interface standards are created, such as navigation and structure of visual elements.

4. A digital prototype is created in the fourth step containing visualisations of the interface.

5. In the fifth step the results are evaluated based on cognitive ergonomics and usability.

3.4.2 Usability testing

Usability testing is a method to evaluate prototypes to find the ease of use and learnability of real users (Haiyan and Baozhu, 2011). The participants preform tasks based on scenarios, short storylines that describe a user preforming a task in a specific use context. This allows the participants to immerse themselves in the circumstances and express their thoughts, needs and suggestions.

Usability testing was preformed as a final activity of the first iteration of ideation. It aimed to identify the traits of the prototype according to usability theory aspects: Useful, usable, desirable, findable, accessible, credible and valuable aspects (Knight, 2019). The participants of the usability testing were industrial design engineering students. They were chosen based on their ability to evaluate the design features of the prototype. The participants were presented with basic knowledge of the industry, common problems and potentials to become familiar with context of the prototype. Digital visualisations were used to present the conceptual product in the form of CAD renderings of the hardware and slideshows of the software. The following use scenarios were created to test some of the functionalities of the prototype:

- Mount the hardware, switch it on and locate the battery level.
- Pair and configure a new device.
- Use the mobile interface to create a fill request.
- Identity the purpose of the four different dashboards in the desktop interface.

The user testing sessions were documented by filming and the participants communicated their thoughts and ideas verbally and trough sketching. The data was transcribed and analysed trough KJ-analysis, where statements were color coded and categorised. The statements determined most relevant were emphasised and brought into the next iteration phase.

4

Result

In this chapter results from executing the methodology are presented. This chapter is ordered in the double diamond development process phases and starts with the result from the discover phase, continues with define and develop phases, and ends with the the deliver phase.

4.1 Discovery phase results

This section includes results which are based on the discovery phase section of the method chapter. These scope of results which are presented includes interview studies, workshop, benchmarking, KJ analysis and opportunity identification.

4.1.1 Interview studies

The study of interview material from the case company revealed statements that were extracted and sorted with KJ-analysis. The statements were interpreted into needs and put into the requirements table (see Appendix 1). The collection of statements and interpretations can be seen in Appendix 3. The statements revealed different contexts where IBC tanks are used, and which issues that comes with them. One example is that when an IBC tank is placed under ground, being used in an oil separating system, it can be fully submerged in groundwater. That creates a demand for solutions that works regardless of the groundwater levels, which was interpreted to the need of a wtaerproof solution.

The second interview study resulted in a collection of statements and a subjective judgement based on these put into the UX-honeycomb (see Figure 4.1). The prototype was used as a mediating object during the interviews and it showed two use scenarios in the mobile app and one in the desktop app. The reactions from the interviewees were generally welcoming, but the desktop prototype management function was the one which sparked the most reaction and reflection. One of the interviewees stated that they would like to see the interfaces of the prototype both in the control room and in the production floor to improve the production planning and flow. The full result of the second interview study is found in Appendix 4.

Figure 4.1: User evaluation of analytic screen.

4.1.2 Workshop findings

Findings from the workshop resulted in many forms of information. The information included short pieces of text written by participants, sketches and images which were browsed online and pasted the digital whiteboard. The workshop was recorded, so statements could also be extracted afterwards. The statements from the workshop were translated, analysed with KJ-analysis and categorized. The results of the workshop were translated in to needs where applicable, and put into the requirements table, see Appendix A.

In figure 4.2 a section of the KJ-analysis process is shown. For the full figure, see Appendix F. The analysis was done in three steps. First, raw data was collected from the workshop exercises. In the second step, the data was sorted and organised into categories. In the third step, a map was created to find overlapping segments of categories. Overlapping segments are shown in Figure 4.2, as bounding boxes with titles in pink, and statements in yellow .

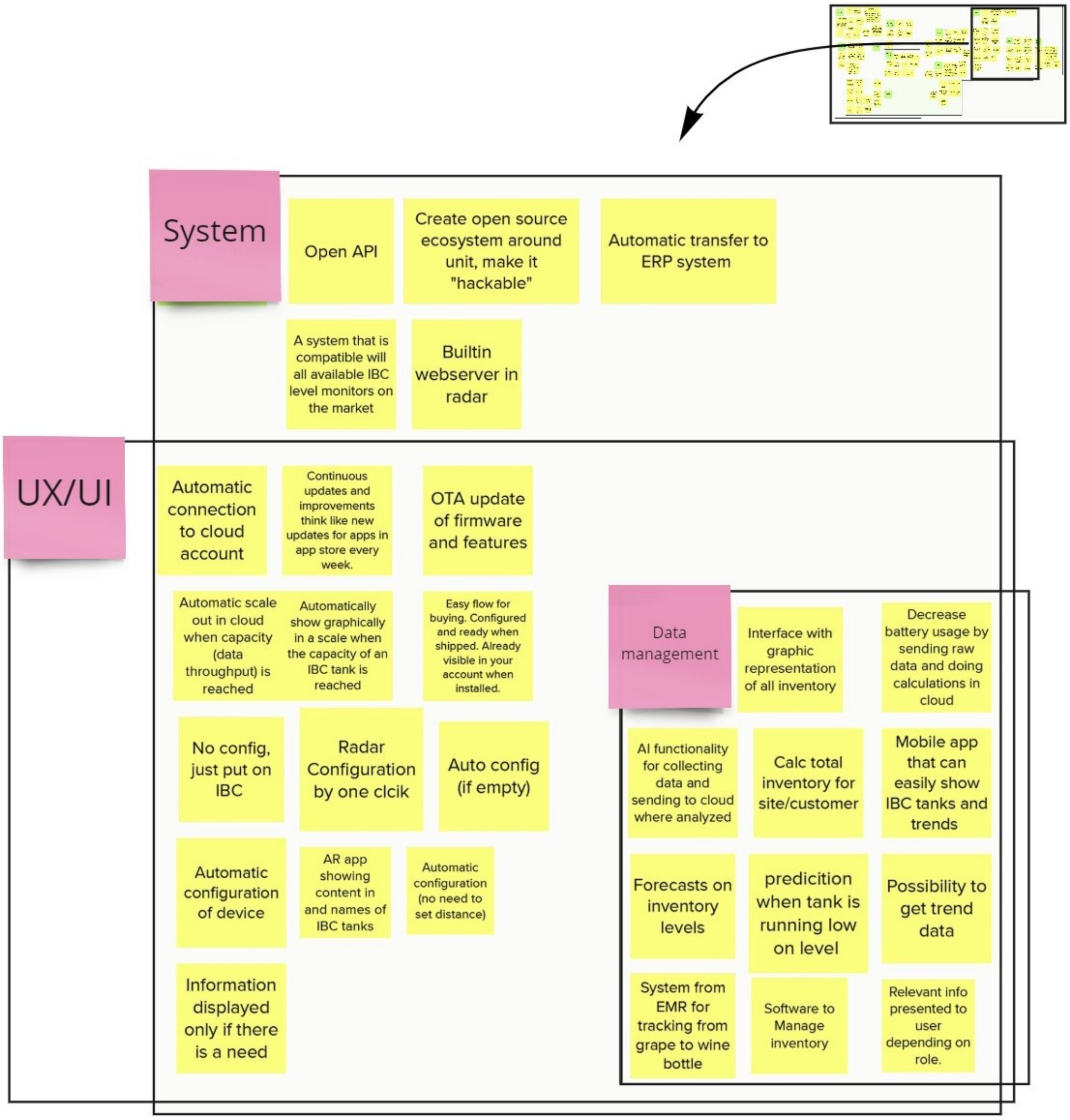

Figure 4.2: A part of the workshop data analysis result.

The workshop data analysis resulted in a list of needs and requirements. These needs was placed in categories related to the product, technical aspects, visionary ideas, economical aspects, durability, security and user experience. The result can be summarised as:

- A general desire to prioritise software before hardware in the business model.
- Subscription based service should be the main revenue.
- The solution should be capable of interaction with other products;
- Integration of AI and machine learning to the software, such as forecasts and trends.
- Data visualisation of inventory history.
- Real time GPS tracking.
- A security system that is triggered by the hardware components.

- A long battery life or a method of energy harvesting to charge the battery
- Robust hardware housing which is capable of withstanding all environments.

4.1.3 Stakeholder mapping

A stakeholder map was made in order to keep track of the stakeholders that were identified during the discovery phase (see Figure 4.3).

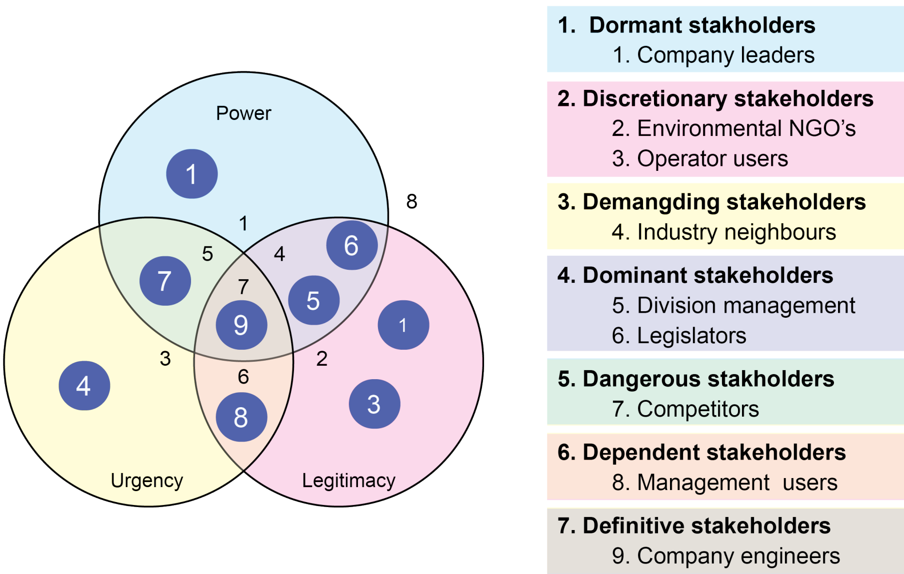

Figure 4.3: Mapping of the stakeholders for the product.

Company leaders were deemed dormant stakeholders as they have power over product lines of the company, but have no reason to use it as long as work run smooth. Environmental NGO's were categorized as discretionary stakeholders since they usually have legitimate but moral claims, but no real power to force their agenda. They will need to cooperate with a dominant stakeholder with power and urgency, such as a legislator, to affect the company. Operator users may have legitimate claims regarding a product, but have no channels to directly affect the company. Neighbours of industrial facilities are seen as demanding stakeholders, as they are directly affected by the industry, and would like to draw attention to their opinions.

The division management of the company is seen as a dominant stakeholder along with the legislators, since they have power to influence and act on their claims. Competitor companies are categorized as dangerous stakeholders, as they have power and urgency to keep their place in the market. Users in management or engineering is seen as dependent stakeholders, as they can have legitimate claims that they want to attention to, but have no own power to change. The engineers and developers working with the project are seen as definitive stakeholders as they hold the power, knowledge and possibility to affect the product. The stakeholders of category 4-7 are the ones with highest salience, and need attention to their claims, while category 1-3 need to be kept an eye on, to notice any shift in placement.

4.1.4 Benchmarking

Benchmarking was preformed on the hardware of four competitive products that fills the need of level monitoring on IBC-tanks, see Figure 4.4. The products chosen for benchmarking were from Endress & Hauser the Micropilot FER30, from Vega the Vegaplus Air 23 and from Packwise the Smart Cap. These measurement devices operate with radar measurements, have GPS and temperature sensors. The fourth solution, from Nanolike have the same functionalities but measure level trough a strain gauge.

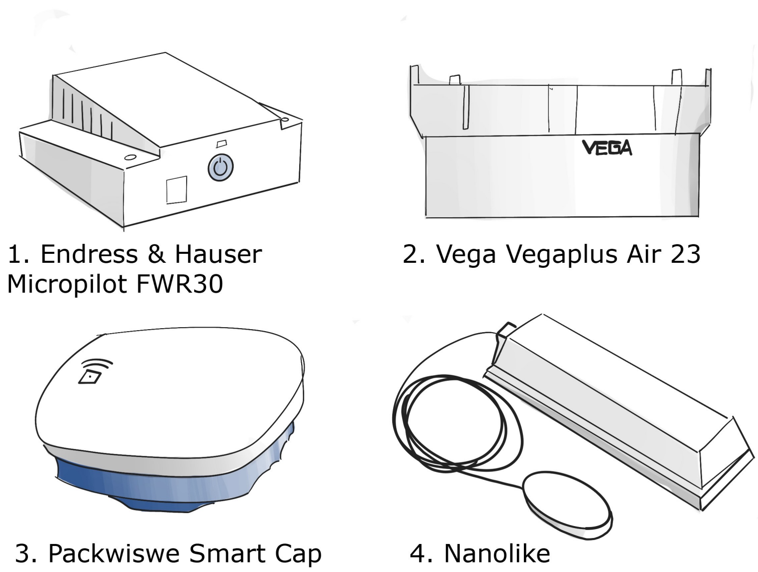

Figure 4.4: The products included in benchmarking.

The most prominent result of the benchmark was that energy supply is something that differs widely between the solutions. The established ones are more sophisticated, and when used as some user would, their battery would last as short as three to six moths. On the other hand, the solutions that were still in testing had less measuring possibilities, but had a lifespan of up to six years.

The software benchmark resulted in listings of functions and visual aspects of the different software and color schemes. The same information were available in both software, but presented with different detail. The color schemes were both based in grey, with the company color as a highlight and red, green, yellow indicating tank level.

4.1.5 Opportunity Identification

To find solutions to some of the software functions discovered in benchmarking, software that had similar functionality were researched in order to find key elements that made them usable.

Task management software
Many functions of these online tools could be integrated into a potential inventory management solution for IBC tanks. These are functions of task organisation connected to task status, priority level, assignee and due date.

Flight radar
Flight Radar is a website that features real time visualisation of air planes on a global map. The visualisation of moving objects attached with specific information is a relevant feature for a the interface that shows tank movements.

Navigation software
Notably Google Maps and Studio NAND's Peak Spotting software. These products show real time visualisations on maps, using data in connection with AI algorithms to predict traffic congestion and give the user suggestions to avoid getting stuck in traffic. The combination of real time GPS tracking being visualised on a map with AI assisted suggestions is a function that might be useful in managing logistics in the software concept.

Financial Data visualisation
The financial industry has a history of storing and presenting large amounts of data. Users can navigate and find information with the help of search functions and screens based on parameters such as key figures, stock price changes, geographical areas and indexes. The data can be presented in different ways depending on what the user find interesting to analyse previous events and future possibilities.

4.2 Definition phase results

Definition phase of this project resulted in a defined selection of product requirements and its system map. These results represented the point of convergence of discovery phase findings and the middle point of the double diamond design process. Therefore, the results which were achieved here served as a foundation for the development and delivery phase execution.

4.2.1 Defining product requirements

The needs found in the analysis of interviews and workshop were used to benchmark competitive solutions. The results of these activities were combined into a table of requirements with 107 individual requirements (see Table 4.1). The full requirements list can be found in Appendix A.

Table 4.1: Twelve of the highest rated needs and requirements.

No	Need	A	T	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
12	Measure level	R	R	R	Yes	Yes	Yes	Yes
32	Wireless connection	R	R	R	Yes	Yes	Yes	Yes
35	Wide connectivity area	R	R	R	Yes	Yes		Yes
106	Battery powered	R	R	R	Yes, D	2 x LS 17500	Probably	Yes
11	Measure temperature (Ambient/Process)	3	3	3	Yes (A&P)	Yes (A)	Yes (A)	Yes (A)
13	Location tracking	3	3	3	Yes	Yes	Yes	Yes
15	Measure tank tilt	3	3	3	Yes	No	Yes	No
60	Simple mounting	3	3	3	Thread, ceiling, wall, IBC	Adheisive, ceiling, belt	Tape/carr plate	Yes
61	Simple removal	3	3	3	Yes	No	Yes	
62	Not hinder stacking tanks	3	3	3	Yes	Yes	Yes	Yes
63	Re-attachable	3	3	3	Yes	Depends	Yes	Yes
64	Plug and play	3	3	3	No	Yes	Yes	Yes

4.2.2 System mapping results

When sufficient data regarding the technical possibilities and user needs was gathered, a final iteration of systems mapping was carried out. The result came in the form of diagrams that represent the suggested configuration of components. The diagrams that were produced was a system map of the entire product and a software user interface tree diagram.

4.2.2.1 Product system map

The systems map is presented in figure 4.5. It presents a broad view of the different sections and components that are included in the product, and how users interact with the hardware through the software.

The product systems map resulted in a configuration of components that are categorized and interconnected. The categories included in the product system map are: User interface, hardware components and external infrastructure. The descriptions of the main categories of the product system map are listed below:

The user interface category of components is situated between the user and the hardware segment of the product system. As the user interface communicates between the user and the hardware it can be identified that it should be prioritised in further development.

The user interface category of the system map has two sub categories: Hardware user interface and software user interface. They are shown in figure 4.5 as circles. The hardware user interface communicates the power switch, battery level and device status directly, without digital device. The software user interface relies on the use of devices as computers and mobile devices to communicate the capabilities. The software user interface also relies on external infrastructure components.

The hardware category of the product system map represents all physical components that were defined in the requirements list. Three components are overlapping with the hardware user interface subcategory, that implies that these are hardware components that have user interface purposes.

The external infrastructure category of the systems map serves the purposes to operate the GPS and Bluetooth components of the hardware and connect the hardware category with the software category.

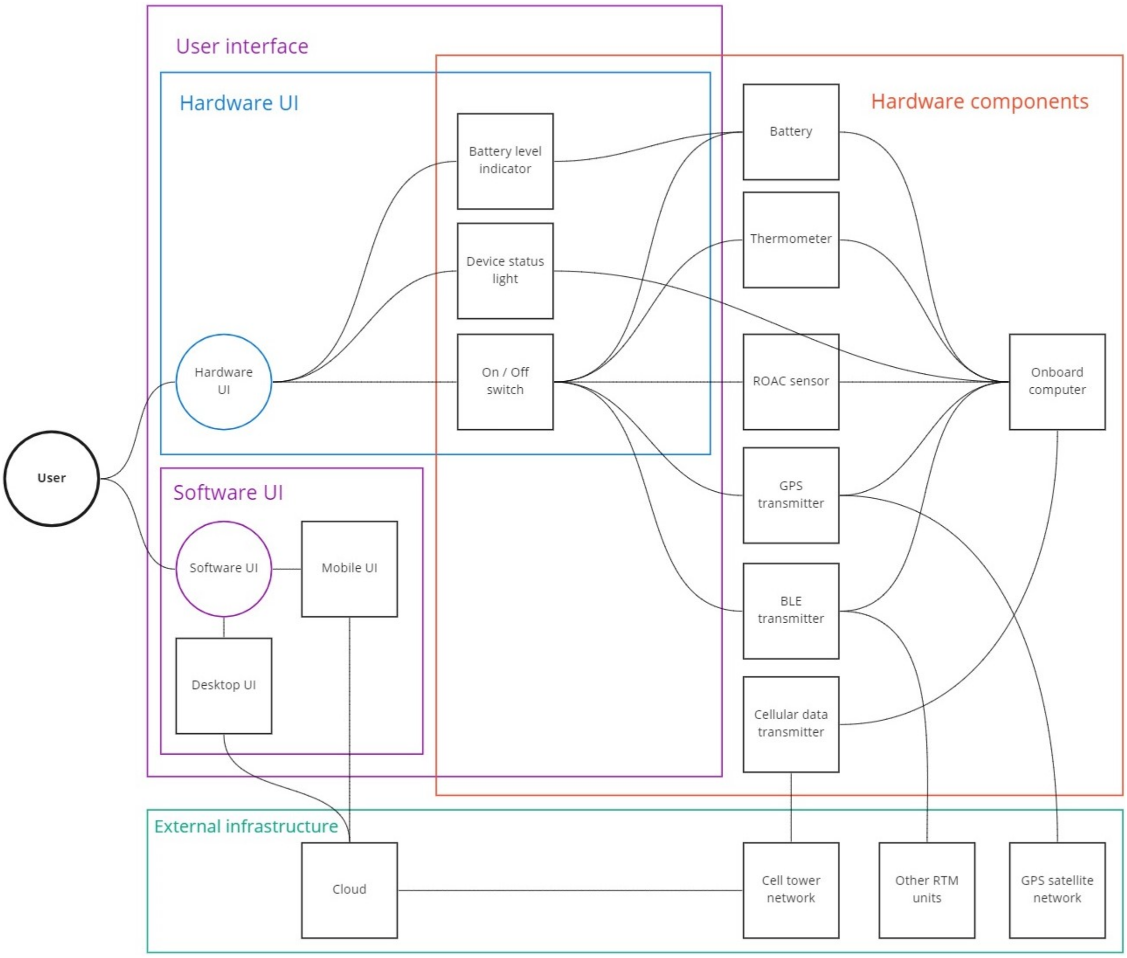

Figure 4.5: General product systems map

4.2.2.2 Software interface tree diagram

A tree diagram of the software user interface was made to guide the user interface design. The diagram shows the software user interface functionalities and their interconnections. The diagram was created based on systems thinking, which emphasises the utility of data visualisation when the amount of data becomes too large to comprehend. A part of the diagram is presented in figure 4.6, and contains one of four sections of the user interface requirements. The full diagram can be seen in Appendix **??**.

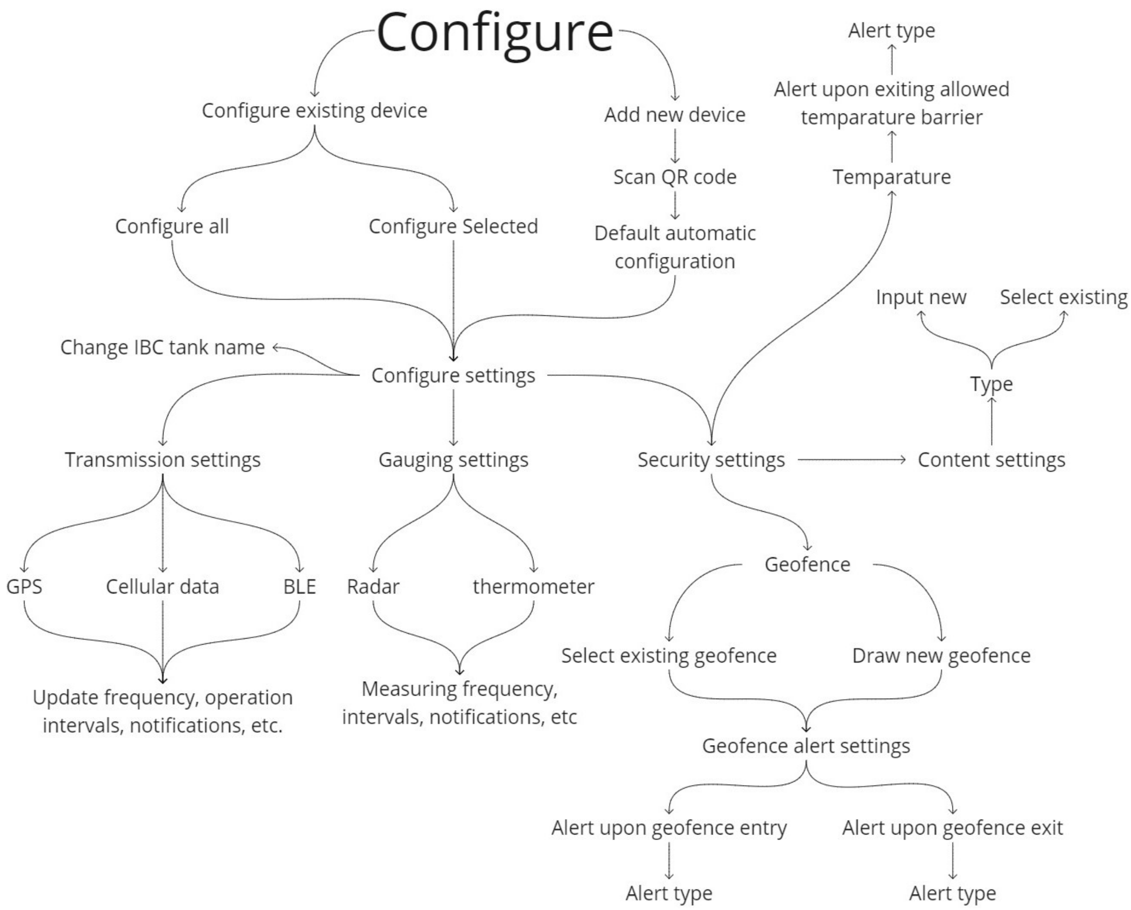

Figure 4.6: A section from the software interface diagram

4.3 Development phase results

In this section of the report the develop phase results are presented. The result from the concept generation is presented in three parts; hardware, network/connectivity and pairing/configuration/user interface (see Figure 4.7). Their contents are briefly explained below:

- **Hardware:** The first part includes concept generation of the hardware unit. It includes concept generations related to physical hardware design and hardware user interface design.

- **Network and connectivity:** The second part includes concept ideas related to connectivity components, networking concepts and integration of connectivity of hardware and software.
- **Pairing, configuration and user interface:** The third part presents results related to concept development of hardware/software pairing, it's configuration process and user interface.

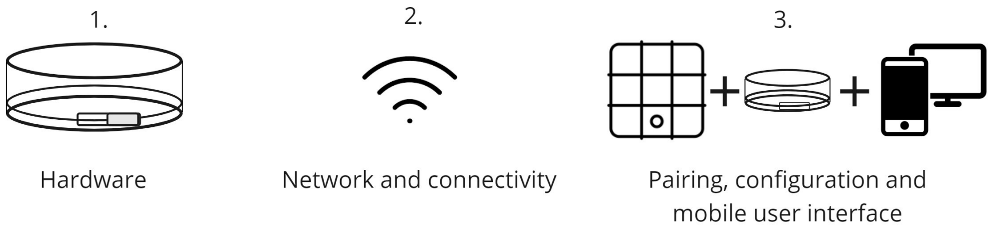

Figure 4.7: The three parts of concept generation results.

4.3.1 Hardware

Although a detail design of the hardware was deemed unnecessary, but the hardware dimensions, shape and design language needed to be defined to create a context for the development of other segments.

Hardware dimensions

Based on information of the battery technology, existing competitors and the shape of IBC tanks, the dimensions of the hardware was approximated (see Figure 4.8). The total height could be up to 8 cm, as it could otherwise interfere with stacking and transportation. The diameter should be around 15 cm. If smaller, some electronics, like the choise of battery might be limited. If larger, it could be difficult to fit the available flat surface on IBC tanks. Being too large could also make it difficult to mount and dismount.

Figure 4.8: Hardware dimension limitations.

Hardware shape and design language

The hardware was conceptualised to be cylindrical, as this type of a shape would enable development of uncomplicated rotational mounting mechanisms, good grip and an simplistic appearance (see Figure 4.9). The design language and product identity was studied during hardware concept development. This could make the product be more recognisable and desirable to use. The design language and identity could be incorporated as hardware shape, logotype placement, packaging and colour selection.

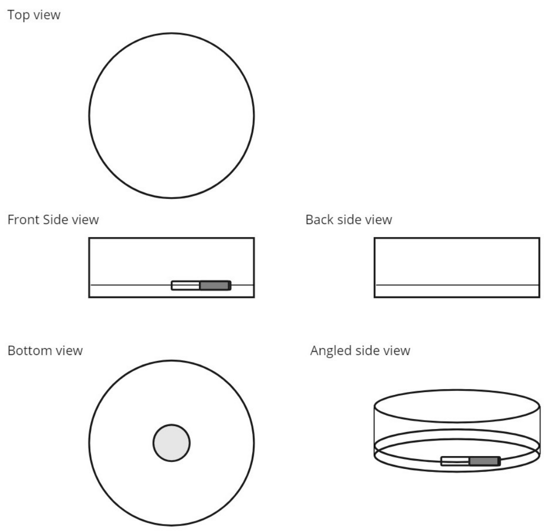

Figure 4.9: Hardware shape.

Hardware user interface

The ardware user interface design was important as it is connection to the user experience and software. The ideation process of the user interface design resulted in the following concepts:

- **Battery replacement:** Battery replacement hatch placed accessibly on the exterior of the hardware.
- **Battery level indicator:** A battery indication concept is presented in Figure 4.10. It shows the LED light configuration for different battery levels. The indicator should be visible on the hardware unit and should have the option to be turned turned off to save battery.

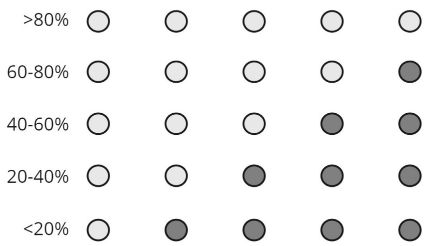

Figure 4.10: Battery level indicator LED concept

- **Status indicator:** A status light concept is presented in Figure 4.11. It indicates a pending management request, assists the configuration process, monitoring status, makes it possible to locate a specific hardware unit. The status is shown by either color or a flashing sequence.

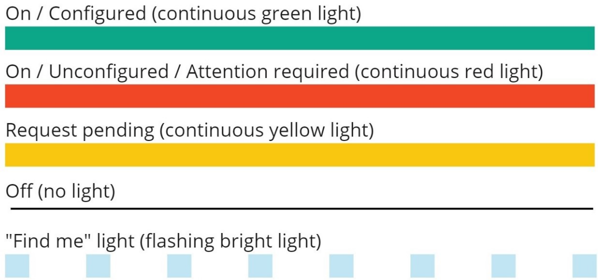

Figure 4.11: Status light concept

- **Hardware mounting:** The mounting process is tied to the configuration of the device and should be effortless. The solution was a disk that is glued onto the IBC tank permanently (see Figure 4.12). The mounting disks should be included in the product to create flexibility of mounting the hardware unit on different tanks. This could be solved with a plastic material and a shape that is easy to produce. The mounting disks can not interfere with the radar signal from the hardware device. This could be solved by removing material from the central part of the mounting disc, see Figure 4.9.

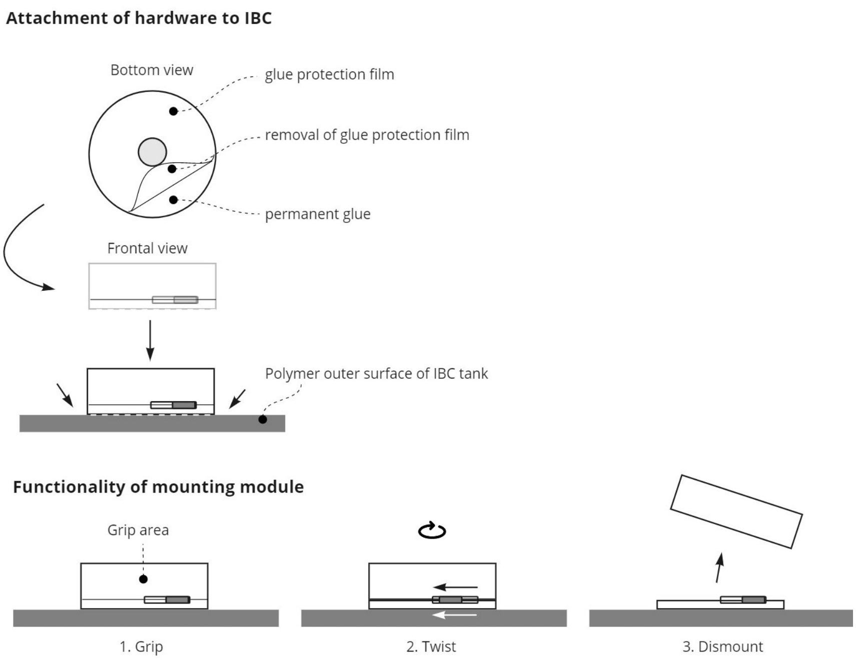

Figure 4.12: Hardware unit mounting to tank.

- **QR code location:** One of the pairing possibilities for a new unit with an IBC tank could be through scanning a QR code. The code should be placed in a location that is easy to find and accessible when tanks are stacked.

4.3.2 Network and connectivity

A connectivity concept was to be developed to make the hardware wireless. It included a combination of connection types to suit different use cases. The connectivity technology chosen was second generation cellular connection (2G), global positioning system (GPS) and Bluetooth low energy (BLE).

2G is based on General Packet Radio Service (GPRS) mobile data standard which includes 2G and 3G cellular communication network's on a global scale. The reason for 2G being chosen for mobile data transfer was the low power consumption, large area-coverage and transmission volume capacity(Perrucci et al., 2009). Due to it's lower operation frequency in comparison with some of the more modern connectivity generations such as 4G or 5G, it uses significantly less power (Mahmoud and Mohamad, 2016). It is a global network standard with a high coverage, which is important due to a need for a good connection globally. 2G also has a transmission volume capacity that is higher than required.

Another connectivity technology which was chosen to be integrated into the concept solution was GPS. It would enable Geo-location, geographical fence (Geo-fence) and related security functionalities. This could be used for higher efficiency in inventory management, with real-time information on inventory locations, and theft protection that notifies of unusual movements.

Bluetooth low energy (BLE) was identified to have potential the hardware unit. The Bluetooth connection would serve the purpose of hardware inter-connectivity, that fulfills the need of tanks being are able to talk to each other. This user need originated from the users desire for a greater battery optimisation of the RTM hardware unit. This technology can also be used to optimize the battery life.

Usability scenario of the connectivity concept

The use of GPS, 2G and Bluethooth in the hardware unit would enable a many functionalities. In order to visually show the capabilities of the concept, a virtual monitoring scheme was created (see figure 4.13). It shows a possible situation where IBC tanks are be scattered in various locations and layouts in a warehouse. This situation was conceptualised in order to describe the technical capability of the connectivity concept.

The use cases shown in figure 4.13 includes a set of different IBC tank layouts which could occur in a real-life scenario. The layouts are marked with numbers from 1 to 5 and each represents circumstances of storing IBC tanks. The scenarios are:

1. Lone IBC tank located outside. Good GPS and 2G signal, but out of interconnection range. Result is good monitoring and location, but bad power and data usage efficiency.

2. Groups of several IBC tanks located outside within interconnection range of

one another. This type of IBC placement enables optimal working efficiency.

3. Small group of IBC tanks outside located out of range of other groups. Monitoring works at medium efficiency.

4. Two IBC groups located indoors with no GPS or 2G connection. They are in interconnection range of one IBC with 2G and GPS connection. If assumed interconnection range is equal to or greater than property boundary distance to Geo-fence distance this can be concidered safe. This means that if interconnection is established, the IBC must be located within the radius of interconnection.

5. A single IBC group located indoors with no external connection, only interconnected with one another.

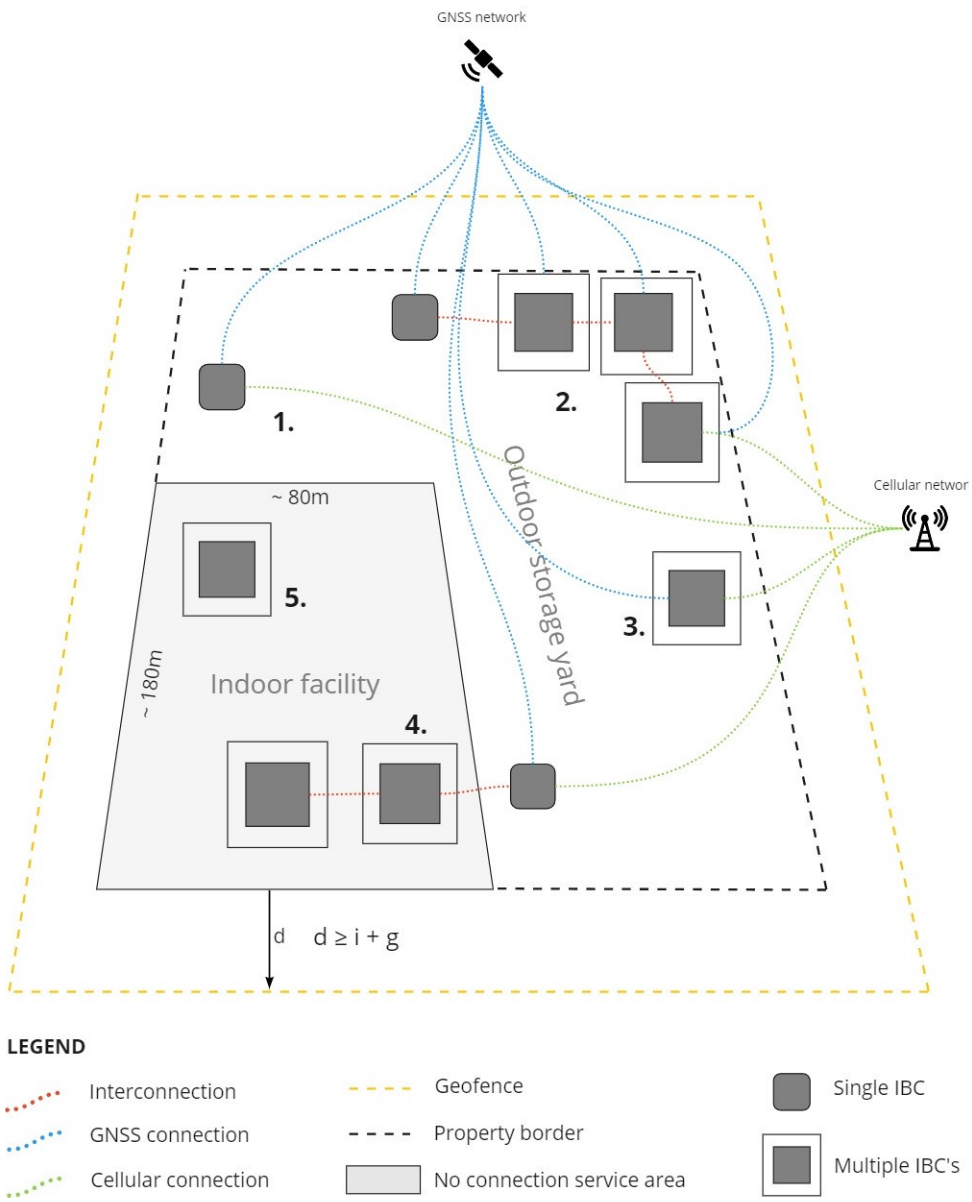

Figure 4.13: Inter IBC connectivity concept.

Impact of connectivity further in the product development process

The Connectivity concept serves as a backbone to the concept, and if altered, it also affects the rest of the product, which can be seen in product system map (Figure 4.5). Therefore the conceptualisation of this segment was done beefor software and hardware design. This also affects the external and internal infrastructure of the hardware. As the conceptual solution includes 2G, GPS and bluetooth, all external infrastructure have to be considered, such as GPS accuracy and reach, 2G coverage and Bluetooth range.

4.3.3 Pairing and configuration

This subsection contains results of pairing hardware with software and the onfiguration process. This stage was carried out after the hardware and connectivity concepts were generated. This meant that in addition to fulfilling the user needs, this result reflect the limitations and features that were conceptualised in the hardware and connectivity concepts.

Pairing

The pairing concept was designed to be effortless. The process was designed in four steps that would complete basic configuration of the hardware. To do the configuration, a mobile device, hardware unit and IBC tank is needed (see Figure 4.14). The process is:

1. Attach the hardware unit to the tank.
2. Log into app on smartphone.
3. Select "add new monitoring device".
4. Scan QR-code on hardware unit.

After successful pairing, there are two options. The first is to use the basic configuration and the second is to specify more parameters for other measurement options. The basic configuration enables vertical level measurement, location, temperature, and default hardware unit name, which is the serial number.

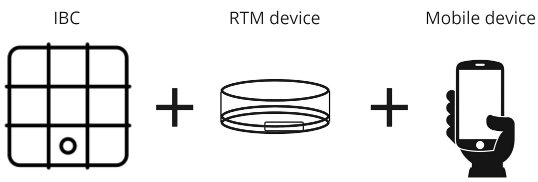

Figure 4.14: Pairing requirements.

Configuration

Further configuration would be possible through both mobile and desktop software. The configuration options include the following settings:

Specify content	Select content type or a create new content.
IBC type	Specifying the tank is necessary to receive the most accurate volume data.
Transmission interval	Select transmission intervals to choose in which time frame the hardware should be active.
Geofence	The category includes settings as selecting existing geofence, draw new geofence, geofence settings, geofence security, transmission settings for a specific geofence, security alarms and notifications settings.
Security	Security settings includes interval settings for theft notifications, notification upon movement and movement outside a geofence and upon temperature interval deflection.
Radar settings	Radar settings includes measuring frequency of passive or intensive.
Thermometer	The thermometer settings include temperature intervals for content requirements and notification for irregular temperatures.

4.4 Deliver phase results

The deliver phase resulted in a conceptual prototype and an user experience evaluation. The prototype was was developed in the segments hardware and software. The hardware segment includes digital visualisations of the prototype and the software includes a mobile and desktop user interface prototype. The prototypes are illustrated in Figure 4.15.

Figure 4.15: Digital prototype of hardware and software.

4.4.1 Hardware digital prototype

The primary aim for the hardware prototype was to facilitate usability testing, to receive feedback of how users would perceive the concept. The digital prototyping of the interface resulted in a series of CAD renderings, that shows the functionalities, see Figures 4.16, 4.17 and 4.18. Figure 4.16 shows the hardware unit prior to being mounted on a tank, paired with the software and configured by the user. It shows the two main components that are the hardware unit and the mounting disk that holds the hardware on the tank.

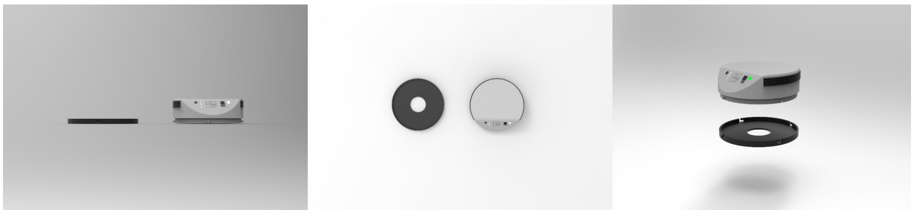

Figure 4.16: The hardware unit and mounting disk.

The mounting process of the hardware unit and the disk is visualised in figure 4.17. The function was designed as a rotational locking mechanism that holds the hardware unit in place. The mounting disk should be considered disposable, as has a permanent, glue-based fixture to the IBC tank. That means the hardware unit can be detached and moved to other IBC tanks, while the mounting platform cannot be removed. The mounting disk has potential to be produced at a low cost, and would be a low part of the product price.

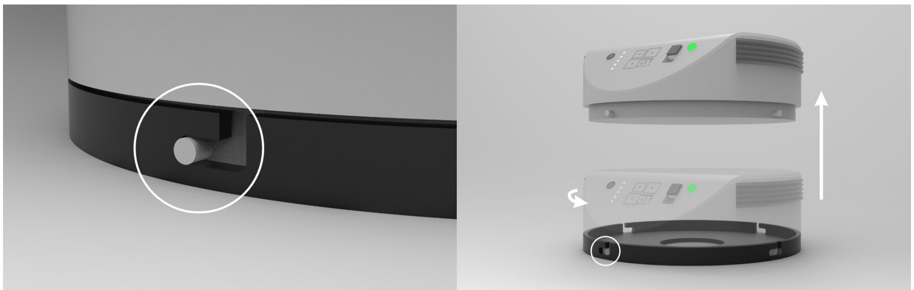

Figure 4.17: Mounting and removal of hardware.

The hardware user interface is visualised in figure 4.18. It is located on a sloped surface on the edge of the cylindrical casing, to be visually accessible from multiple angles. The specific components of the hardware interface are numbered from 1-5 and serve the following purposes:

1. Battery level indicator switch.
2. Battery level indicator.
3. QR code.
4. Power switch.
5. Status indication light.

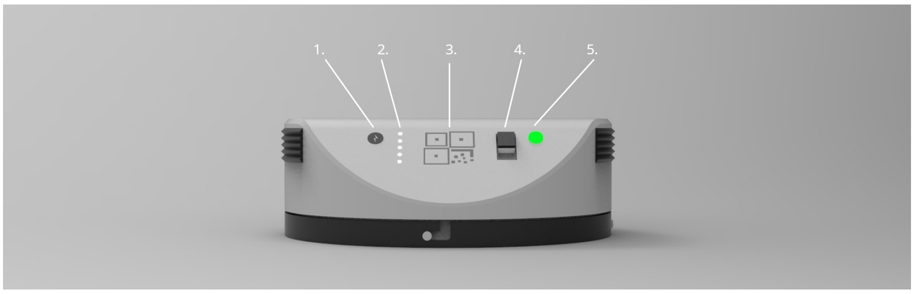

Figure 4.18: Hardware user interface control panel description.

4.4.2 Mobile user interface

The mobile user interface was designed primarily for pairing IBC tanks with the hardware units, but would also have simplified functions from the desktop user interface. The functions included a simplified analysis tool, inventory navigation, hardware configuration and management functions. The mobile user interface is shown in figures 4.19 and 4.20.

Figure 4.19 shows the basic navigation features of the mobile application. This feature is always accessible to keep track of orientation and progress. Navigation function includes a menu with a main menu, located at the bottom, buttons for settings, search and profile located in top of the interface.

Figure 4.19: Navigation in the mobile application.

The main app functions that are presented in Figure 4.20 are log in page, navigation, analyse, manage and connect.

Figure 4.20: Mobile application interface.

Log in

The application is accessed through a login page. The option of logging in is necessary based for data security. Companies or different individual users could have different types of access to data depending on the settings configured by the administrative user.

Navigate

The landing page of the application is navigate. The user is presented an overview of all active hardware units on a map. The user can navigate through the inventory and find an individual or a collection of tanks. The inventory can be navigated in the following ways:

Map	Navigating through inventory in the map can be useful when many IBC tanks are spread across different locations.
Text search	The search bar is permanently located on the top of the user interface. A search can be performed by content type, name, serial number or location. This can be useful in situations when any of the information is known prior to searching.
Filter input	If the search needs to be narrowes, search filters of content type, filling level, battery level or location can be used
List	By scrolling through a list to find a tank could be useful when the number of tanks is small.

Analyse

The analyse function has basic capabilities of showing current tank status and historical data. The current tank status can be monitored through an indicator box that was designed to present the most important information about the tank in a compact space. An example of a status box is shown in Figure 4.21.

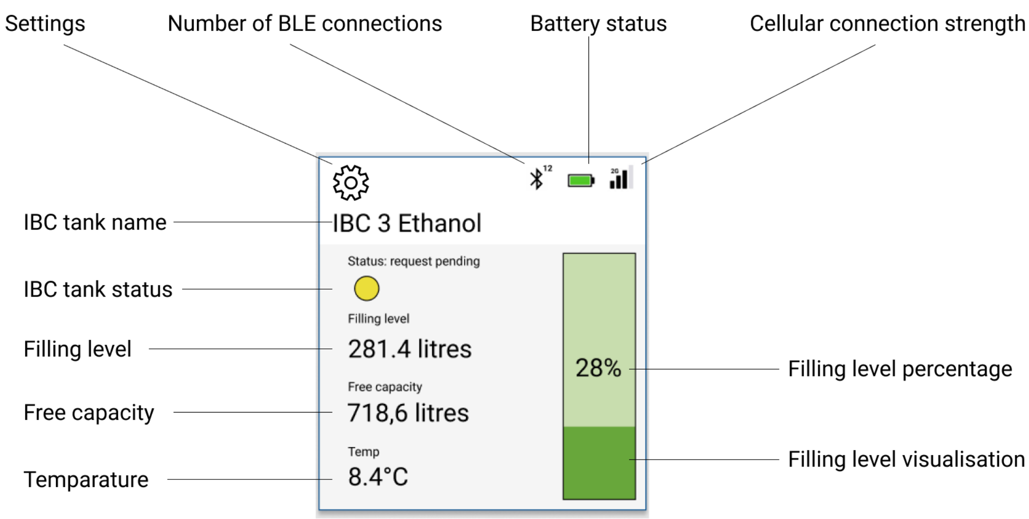

Figure 4.21: IBC current status indicator box.

The historical data shown in the analyse section is previous locations, fill level history , temperature history, battery status and management request history. Unlike in the desktop version, the mobile user interface is only analyse one IBC tank at a time or all IBC tanks simultaneously.

Manage

The management function was designed to connect maintenance with management. Management can request maintenance to be resolved. If a task cannot be executed at that specific point in time, it could be rescheduled and the tank status status would change.

Connect

The connect function serves the purpose of pairing hardware with software. The process of pairing uses the QR-code scanner or serial number input and has optional configuration steps to optimise the battery life, security and data output.

4.4.3 Desktop user interface

The desktop user interface was designed to function along the mobile app, and has similar usability and functionality. The visual identity and navigation principles were designed to match the mobile application, as this would enhance the user experience when switching platforms. The main difference between the mobile and desktop interface is their purpose. The focus of mobile application is to pair new devices and execute management requests, and the desktop application focus analysis and management. The desktop interface was designed to facilitate analytic tasks and management operations, benefiting from the larger screen.

Desktop user interface layout

A presentation of the desktop prototype is shown in figure 4.22. The main layout functions are a navigation bar in the bottom, a selection tool, and a profile icon for preferences and logging in and out. There is also a search bar, content titles and spaces.

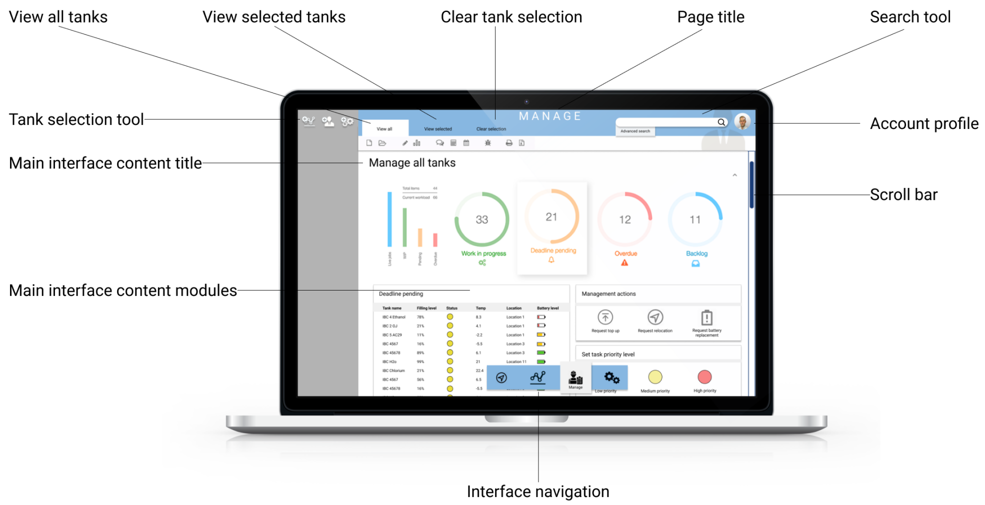

Figure 4.22: Desktop user interface layout.

Desktop application sections

The desktop applications has four main sections and several subsections that contain different functions. The main sections are shown in Figure 4.23. The purposes of the sections are

Navigate: Locate tanks.

Analyze: Analyze data received from hardware units.

Manage: Send management requests, such as scheduling maintenance, relocation or refills.

Configure Configure the technical specifications of the hardware unit.

Figure 4.23: Desktop user interface sections.

In Figure 4.23 the landing pages of the different sections are shown. The individual functions of each specific section are specified in Table 4.2. It describes functions that global to the applications and unique functions in the different sections. A location description of individual functions is listed to help locating them.

Table 4.2: An overview table of desktop user interface functions and features.

Section:	Function:	Location:	Feature/tool:
All sections	Select multiple tanks	Selection tool interface	Selection tool
	Browse	Search bar (top right corner	Keyword search feature
	View profile	Profile icon (top right corner)	Profile information and configuration page
	UI navigation	In the middle of the bottom part of the UI	UI navigation bar
Navigate	Browse	Landing page central interface	Interactive geographical map
		Advanced search tab	Categorical search filters, inventory list
Analyse	Overview	“View all tanks” tab	Key performance indicators box
	Analyse all tanks	“View all tanks” tab	Interactive overview charts, interactive inventory list.
	Analyse selected tanks	“Selected tanks” tab	Interactive overview charts of selected tanks, interactive charts of individual tanks (based on categories such as filling level history, battery consumption, use frequency, relocation frequency, temperature history, etc.), interactive inventory list of selected tanks, location history box, management request history.
	Clear selection	“Clear selection” icon	Clear selection function for Analyse section
Manage	Tank management activity overview:	“Manage all tanks” tab	Key management indicators box, active tanks tab, deadline pending tab, overdue requests tab, Request backlog tab.
	Place request	“Manage selected tanks” tab	Maintenance, fill up, relocation, content replacement,
	Adjust request	“Manage selected tanks” tab	Change request status, change request type, delete request.
	Clear management selection	“Clear selection” icon	Clear selection function for Manage section
Configure	Modify Individual RTM unit settings	“View all tanks” tab	Interactive inventory list of all tanks, update frequency tool, security settings tool, geofence configuration tool, temperature interval adjustment tool, radar settings, GPS settings, GPRS settings, BLE settings.
	Modify bulk IBC settings	“Configure selected tanks” tab	Interactive inventory list of selected tanks, bulk RTM unit configuration tool.
	Clear configure selection	“Clear selection” icon	Clear selection function for Configure section

In order enhance the experience of browsing, a navigation feature for quick data display was designed. This purpose of this feature is to show highlights of general information about individual IBC tanks before they are selected for further analysis, management or configuration. The information is shown in a popup box when clicking or hovering over a tank object in the map (see Figure 4.24). To the left of Figure 4.24, the hovering function is shown, and on the right clicking clicking fuction.

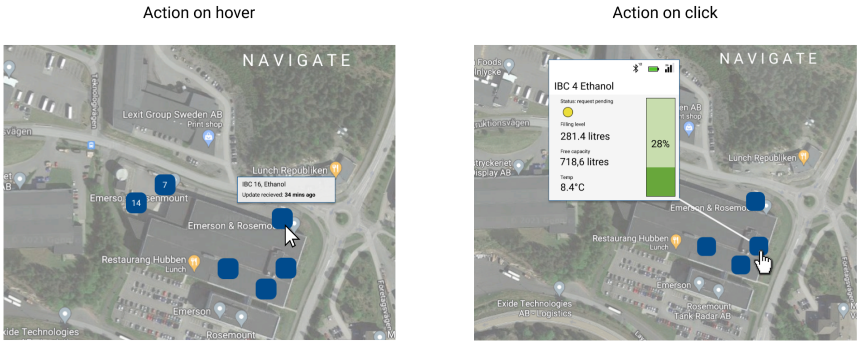

Figure 4.24: Quick data display function.

A function that was thought to have potential to increase the functionality of the application was the selection tool (see Figure 4.25). The tool is present globally in the application, located on the left side of the screen. It is hidden until a selection is made to not occupy unnecessary space while not in use. It's principle function was inspired by the add to cart function that is common in online shopping websites. Bulk selections are possible and selections can be diverted to specific sections of the application (see the top of Figure 4.25).

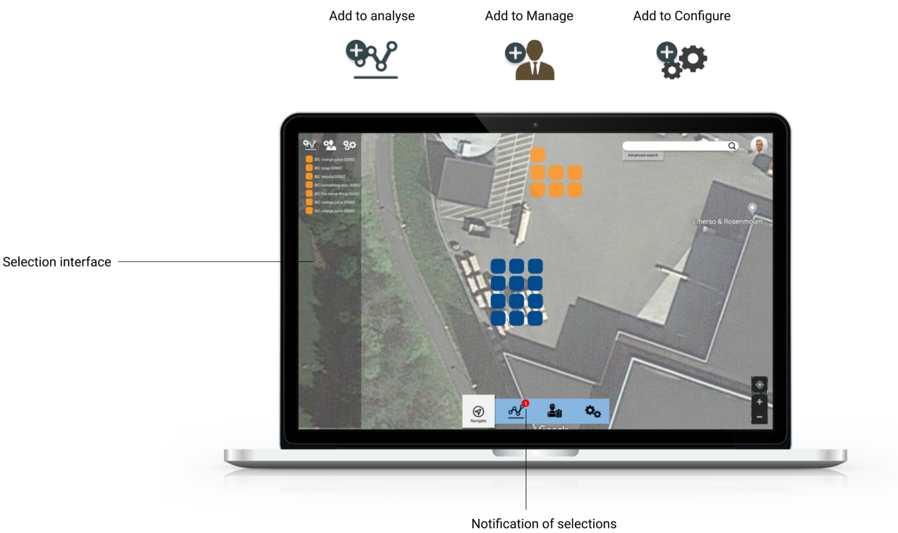

Figure 4.25: Selection tool.

4.4.4 Usability testing

Usability testing resulted in a collection of statements. It was compiled to show the findings, their level of relevance and categorisation. The result was used mostly to reiterate the develop and delivery phase and for stating future development opportunities.

A part of the usability testing result is shown in figure 4.26. The full results can be found in Appendix E. In the upper section of the Figure, a row of sticky notes is arranged to show from which scenario the data originate from. The titles connect to the statements by colour. for example; all blue sticky notes originate from the hardware usability scenario. In the figure it is also possible to see the level of relevance of each statement by looking at their sizes.

Figure 4.26: A usability testing result example from one user.

5 Discussion

The result of the user studies played an important role in this project. By engaging both engineers from the case company and potential users, a wide variety of statements could be collected. The first part of the interview study was made on already collected material, and there is a possibility that opportunities were missed. Regardless of the limitation, a lot of information came out of the analysis, and contributed to the result. The second round of interviews were done with two participants, which gave a limited amount of information. The participants were highly invested in the process industry and both had long backgrounds in different companies, which gave high quality to the statements they made. The result would have been more solid if more participants had been found both rounds of interviews.

The workshop resulted in a large amount of data, with a focus on possible technical solutions, which provided context to the hardware possibilities. There is also a possibility that hidden user needs emerged from the engineers knowing the users from previous project. While the workshop was successful, the process could have been improved by dividing more time to actual execution of the activity to have more possibilities for discussing the findings with participants. The benchmarking was made on four similar solutions from four different companies. This gave a context to what the state of technology is for the product segment, but did not reveal any differentiating possibilities. The opportunity identification served as a good base for designing functions, but could have been extended even more to get a wider input of information.

The definition, or narrowing down of the identified user needs could have been more comprehensive. The methodology suggests that the project team rates the relative importance of needs. The project team consisted of only two individuals, so the results may have been biased. If the requirements list should be used in future development, the rating should be remade, with at least five people who are knowledgeable of the industry.

A conceptual framework emerged from the concept generation. The conceptual framework quality could be improved through the re-iteration of the user requirement prioritisation and rating in the definition phase, as well as with more time dedicated towards the development. A re-iterated user requirements list would mean that the base of the conceptual framework would have less bias. With more time available for development, more concept generation iterations could be conducted which could have resulted in more ideas.

The prototype only shows a part of the solution. Due to resource and time limitations, only the essential capabilities were presented. A a future opportunity could be visualising the functions that were not included in the prototype. This could benefit the presentation quality of the conceptual framework and user requirements. In addition, the number of iterations in the digital prototyping were few. That meant that the result from usability testing did not have the opportunity to translate into changes on the prototype. In potential future development, this could be solved with more time dedicated towards digital prototype development.

This project aimed to identify and define user needs and requirements for developing a remote monitoring system for mobile plastic tanks and present them as a conceptual solution, focusing on user experience and human factors. By doing this, a set of research questions would be answered. The question of who the stakeholders are, in which industries they work and what their needs are was answered by the user studies, that found most of the stakeholders in the process industry or within the case company. The needs of user stakeholders were found to focus on ease of use and visual representation of information from their production.

The answer to the question of what a theoretical framework would look like was found to be that a systems thinking approach is useful when developing a hardware/software combination, in order to comprehend all connections that need to be established. The human factors aspects that were found relevant focused on the visual representations of objects, in form of the gestalt laws. The question of how the solution could be visualised is answered by the results. The feedback that was generated from the usability testing and second round of interviews showed that the visual representation of the concept lived up to what the users would expect.

5.1 Ethical considerations

Assuming the concept that was developed would be implemented in reality, it would cause some ethical dilemmas that should not be overlooked. As the concept places itself into the category of automation and digitisation, the topics of workforce being replaced by robots, increased workforce control, increased necessary screen time of employees, increased reliance of digital devices and other health considerations should be reflected upon.

If the system would be implemented, it would likely lead to a reduction in workforce, as processes as inventory monitoring done manually would be automated. Tasks as inventory management that previously required several workers would be conducted by a single worker. Eventually, artificial intelligence could learn repetitive human input sequences and automatise them, making human labour redundant. This raises the question if it is ethical to replace human labour with automated processes, leaving unskilled labourers out of work, and subsequently making it harder for people of low socioeconomic status to find jobs. Since the concept allows for worker being tracked through GPS data and historical timestamps in the system, it would create added stress or feeling of oppression to the workers who are working with the IBC-tanks. A negative possibility of this would be that workers could become too controlled by management, leading to bad work environment with health effects on the workers

Another concern would be the increased reliance on digital devices, as screen time has negative effects on humans, both physically and mentally. Digital presence in the workplace directly improves the physical strain on the workforce, an therefore, it is difficult to tell if digitisation is doing more harm than doing good. The final concern of implementing concept would be the increased radiation in the immediate vicinity of the hardware units, as it would be emitting microwaves, Bluetooth low energy transmission, cellular transmissions and GPS. That could possibly effect the health of workers spending prolonged time around the system.

5.2 Sustainability

The implementation of the concept could have environmental effects. Some of these effects might be positive and some negative. The positive ones could be that digitising and automatising tank monitoring and management would lead to materials being used more efficiently. Material stockpiles would be smaller, less tank content would be have to be discarded or recycled due to them being expired.

The negative environmental impacts of a system like this are expected to be minimal relative to the benefits, but they do need to be considered as ecology is one of the most prevailing necessities of our time as a civilisation. The biggest negative environmental impact which this system would bring is through the hardware. Due to the hardware being technologically complex, it's construction, recycling or disposal would leave a footprint in the environment. This footprint would mainly represent the carbon dioxide emissions which were used when producing and transporting it. The chemical footprint of the battery and the disposal footprint of components which cannot be recycled, mainly polymers and electronics, need to be considered. This could be done by taking a circular approach when choosing components and designing the business model.

6

Conclusion

Radar technology has become smaller and cheaper, which has enabled the development of level measurement radars for the variety of mobile plastic tanks commonly known as IBC tanks. This project followed the double diamond process to develop a conceptual remote tank monitoring system for IBC tanks. Information about the market and end user was gathered trough interviews, benchmarking and a workshop in the divergent Discover phase. The most valuable insights of this phase came from the benchmarking, where a weakness in the competitor solutions power supply was discovered.

The information gathered was analysed and transformed into a needs and requirements list in the convergent Define phase. The needs were rated, where the most important needs, and all requirements were displayed in a systems map. The most important needs and requirement regarded the connectivity, that needs to cover large areas and have several sources, such as Bluetooth and cellular connection. The systems map showed the three segments needed for the concept; hardware, software, their respective user interfaces and external infrastructure.

In the divergent Develop phase, the user needs were conceptualized into a remote tank monitoring system, based on the systems map. The concept was visualized in a hardware unit, a mobile interface for simple tasks and a desktop interface for managing and analysis. The prototypes were evaluated trough usability testing in the final, convergent, Delivery phase, trough usability testing and interviews. The usability testing revealed some minor design flaws, such as unrecognizable symbols, but showed that the prototypes otherwise were easy to understand. The interviews were conducted with managers of engineering background in the process industry, who saw great benefit to their processes in some of the features that showed tank levels and statuses.

The final concept resulted in a comprehensive solution that presents both hardware and software in a understandable way that is exiting for the end user and highlights features that would put this concept in the front of its competitors.

For further work, the following activities are recommended:

- The interviews in the Deliver phase was conducted with two individuals, and need to be extended with more participants from different industry to get a more comprehensive and reliable result.

- The rating process of the needs and requirements list was done with focus on the context of the project, which probably have given led to a bias towards user experience friendly features. The needs and requirements list should be re-iterated and the rating should include a broad spectrum of competencies.
- The power supply was found out to be a weakness for this kind of remote tank monitoring. It now relies in batteries, but more research is needed to improve the possibilities of a more durable power supply.
- No physical prototype was made of the hardware. In order to ensure that all technology fits in the housing and that the user interface is functional, a physical prototype needs to be developed and tested.

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A

Appendix 1

Appendix 1 contains the table of requirements (see Table A.2). The colors used in some cells are explained in Table A.1 Number 12, 32, 35 and 106 were identified to be requirements, the rest were considered needs..

Table A.1: Description of color meanings in the requirements table.

Green	Need discovered from interview study
Yellow	Need discovered from workshop
Red	Need discovered from benchmarking
Blue	Need discovered from other sources

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
2	Business model							
3	No fuss business model so that engineers doesn't need to fight purchasers	3	1	2				
4	System for selling subscribtions	3	1	2			Seems so	
5	Business model for customers to be distributors of hardware	1	1	1				
6	Marketplace for raw materials	2	3	2.5				
7	Marketing							
8	Clear marketing, visibility to customers needed	2	1	1.5				
9	Safety can be higher withn alarms. Quality can be higher with monitoring	2	3	2.5				
10	Sensory measurments							
11	Temperature (Ambient/Process)	3	3	3	Yes, -20-60°C (A&P)	Yes (A)	Yes (A)	Yes (A)
12	Level	R	R	R	Yes, 0-15m	Yes	Yes	Yes, strain gauge
13	Location	3	3	3	Yes, +/- 20m	Yes	Yes	Yes
14	Vibration	3	2	2.5	No	No	Yes	No
15	tilt	3	3	3	Yes, 0-180°	No	Yes	No
16	Device position on IBC	3	3	3		Yes		
17	Device status	2	3	2.5		Yes		

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
18	Alarms							
19	Dangerous trends	3	3	3	Yes			
20	Leakage	3	3	3				
21	Near empty	3	3	3				
22	Overfilling	1	1	1	Yes	Yes		
23	Low battery	3	3	3	Yes, light	Yes		
24	Tilt	2	3	2.5			Yes	
25	Strange movement (time/location)	2	3	2.5		Unit not safe for transport	Theft protection	
26	Temperature	3	3	3	Yes	Yes		Yes
27	Low stock	3	3	3				
28	Clean antenna	1	1	1				
29	Connectivity							
30	Connectivity options	1	1	1	Mobile data, radio	e-sim, radio, NB-IoT,LRWAN		
31	Enabling customer to use their own communication infrastructure	2	1	1.5		Yes		
32	Wireless option	R	R	R	Yes	Yes	Yes	Yes
33	Option for no cloud	2	1	1.5	No			No
34	Option for wire data transfer	2	1	1.5	No		No	No
35	Connectivity area needs to be large	R	R	R	Yes, mobile data/radio	Yes		Yes

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
36	Safety							
37	Applicable for safety standards in diferent industries	1	1	1	Yes			
38	Data for safety should apply with regulatory entities (and neighbours)	1	1	1	Yes			
39	ATEX rating (is crucial for flammables)	1	1	1	No	No		Yes
40	Turn off radar where it is not allowed to measure (geofence) ?	2	3	2.5		Patent		
41	Geofencing	3	3	3				
42	Maintnance							
43	Easy, preferrable automatic calibration	2	3	2.5				Yes
44	Data for optimizing maintnance schehule	3	3	3	No Repairs			
45	Minimizing labour							
46	System for automatic rounds on lube oil	2	3	2.5				
47	Radar measuring would decrease the need of moving IBCs while counting inventory	3	3	3				
48	Less calibration and less messes	3	?	3				
qq 49	System for automation on simple processes	1	1	1				
50	Hardware							
51	Handheld system	2	?	2	No	No	No	No
52	Need some IP classification for waterproofing	3	?	3	IP66, IP68, NEMA 4X/6P	IP69		

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
53	Measuring on emulsified oil/water mix	1	1	1				
54	Needs to work with splashing and foaming products	1	1	1				
55	Needs to work on grease separating systems	3	2	2.5				
56	Needs to work with steaming products	1	1	1				
57	Universal system for all viscosities	1	3	2				
58	GPS dormant while not in move	3	3	3				
59	Reusable	3	3	3				
60	Simple mounting	3	3	3	Thread, ceiling/wall, IBC	Adheisive, ceiling, belt	Tape/carrier plate	Yes
61	Simple removal	3	3	3	Yes	No, Single use adhiesive	Yes	
62	Not hinder stacking IBCs	3	3	3	Yes	Yes	Yes	Yes
63	Re-attatchable	3	3	3	Yes	Depends	Yes	Yes
64	Plug and play	3	3	3	No	Yes	Yes	Yes
65	Visual localisation of radar unit	2	3	2.5				
66	Automatic calibration	3	3	3				Yes
67	Save battery trough optimized data sending	3	3	3	Kind of			
68	RFID/NFC	2	3	2.5		some NFC function		

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
69	Battery indication	2	3	2.5	When low			
70	Scanner	1	?	1				
71	Option for threaded mounting	2	?	2	Yes	No (But have other solutions	No	No
72	High accuracy	3	3	3	+/- 10 mm	+/- 5mm		100 l
73	Process temperature	2	2	2	-20 - +60 °c	-20 - +60 °c		
74	Systems data exchange							
75	Forklift/logistics	3	3	3				
76	Work orders for production	1	3	2	Supports tickets		Yes	
77	Automatic work orders for maintenance	3	3	3				
78	Automatic connection to first responders to minimize the effects of accidents	2	3	2.5				
79	Connected to recipe system and business system	2	2	2				
80	Level data available to both subscriber and supplier	1	2	1.5				
81	Out data compatible with different systems	3	2	2.5			No	No
82	Connection with tank emptying companies for oil sepatators	2	1	1.5				
83	Connect with current backoffice	2	1	1.5	Yes			
84	Custom mesurement intervals	3	3	3	?, 1min-8h	<{}5 s		

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
85	Custom transmission intervals	3	3	3	15 min - 24h	15 min - 24 h (when ordering)		
86	Radars can "talk" to eachother	2	3	2.5				
87	Connect specific IBC to specific radar	2	3	2.5				
88	FTD standard data excahnge	3	3	3	Yes			
89	Data visuals							
90	Options for different measurment units	3	3	3				
91	Visual of volume left	3	3	3				
92	Needs to make differens between many different contents (200+)	3	3	3				
93	Bird wiew on IBCs (with content could be sufficient in some cases)	2	3	2.5				
94	Accuracy in both length and litres	3	3	3				
95	Fast/live updates for quicker fills	1	2	1.5				
96	Radar battery health	2	3	2.5				
97	3D visual of tank fleet	2	2	2				
98	Forecast on stock/levels	3	3	3	Yes			
99	Cellular connection strength	2	3	2.5				
100	Agumented reality options	1	3	2				
101	All radar units on a map	3	3	3				
102	Tank free capacity and fill level	3	3	3	Yes			
103	Update frequency	2	3	2.5				
104	BBF-date monitoring	1	3	2			Yes	

Table A.2: Requirements table.

	Need	R1	R2	Avg	E&H Micropilot FWR 30	Vegaplus air 23	Packwise	Nanolike
105	Battery							
106	Battery	R	R	R	D, changeable	2 x LS 17500	Probably	Yes
107	Energy harvesting	3	1	2	No	No		
108	Wireless charging	3	1	2	No	No		
109	Long life	3	3	3	∼140 days/max usage	6/18mo on max usage		6 years
110	Simple battery change	3	3	3	Yes	No		
111	System, general							
112	Open API	1	1	1				
113	Built in web server	1	1	1				
114	Compatible with non RTR radars	2	1	1.5				
115	Automatic software updates	3	3	3	Yes			
116	Relevant info for user depending on role	2	3	2.5				
117	Desktop, mobile and tablet	3	3	3	Yes			Seems so
118	Automatic configuration	3	3	3				
119	App store	2	3	2.5				
120	Key-chain for unit passwords	1	1	1	Yes			

B

Appendix 2

Appendix 2 contains the software user interface tree diagram which was only partially shown in the definition phase part of the results chapter. It is presented in four parts. Part 1 (figure B.1)contains UI features related to Navigation section, part 2 (figure B.2) presents the Analyse section features, part 3 (figure B.3) the management user interface section, and part 4 (figure B.4) the configuration section.

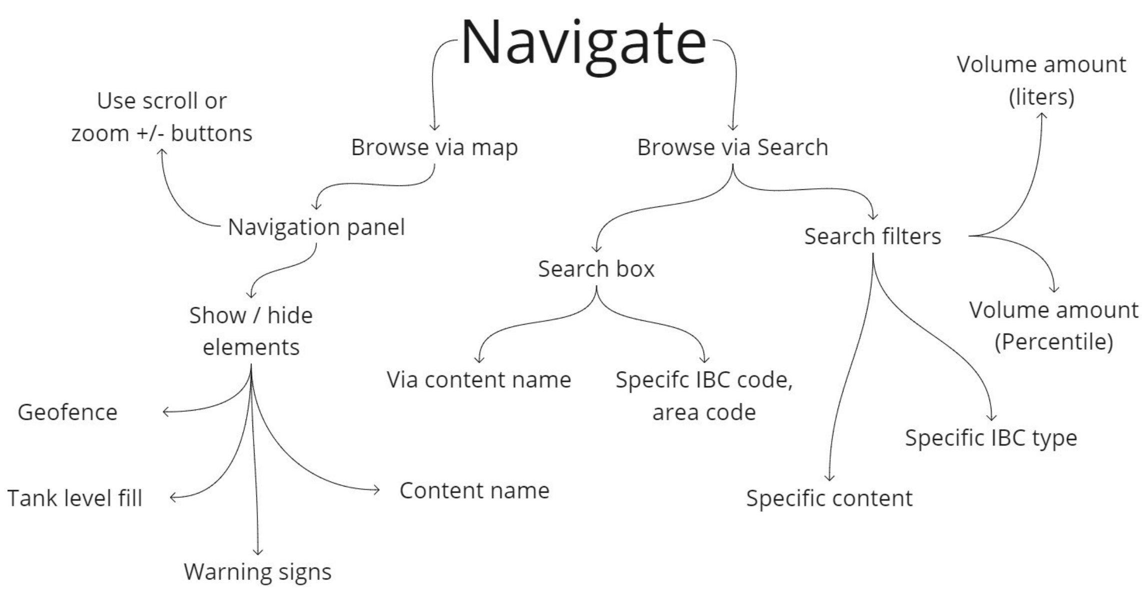

Figure B.1: Part 1 of appendix 2: Function diagram of the Navigation section of the user interface

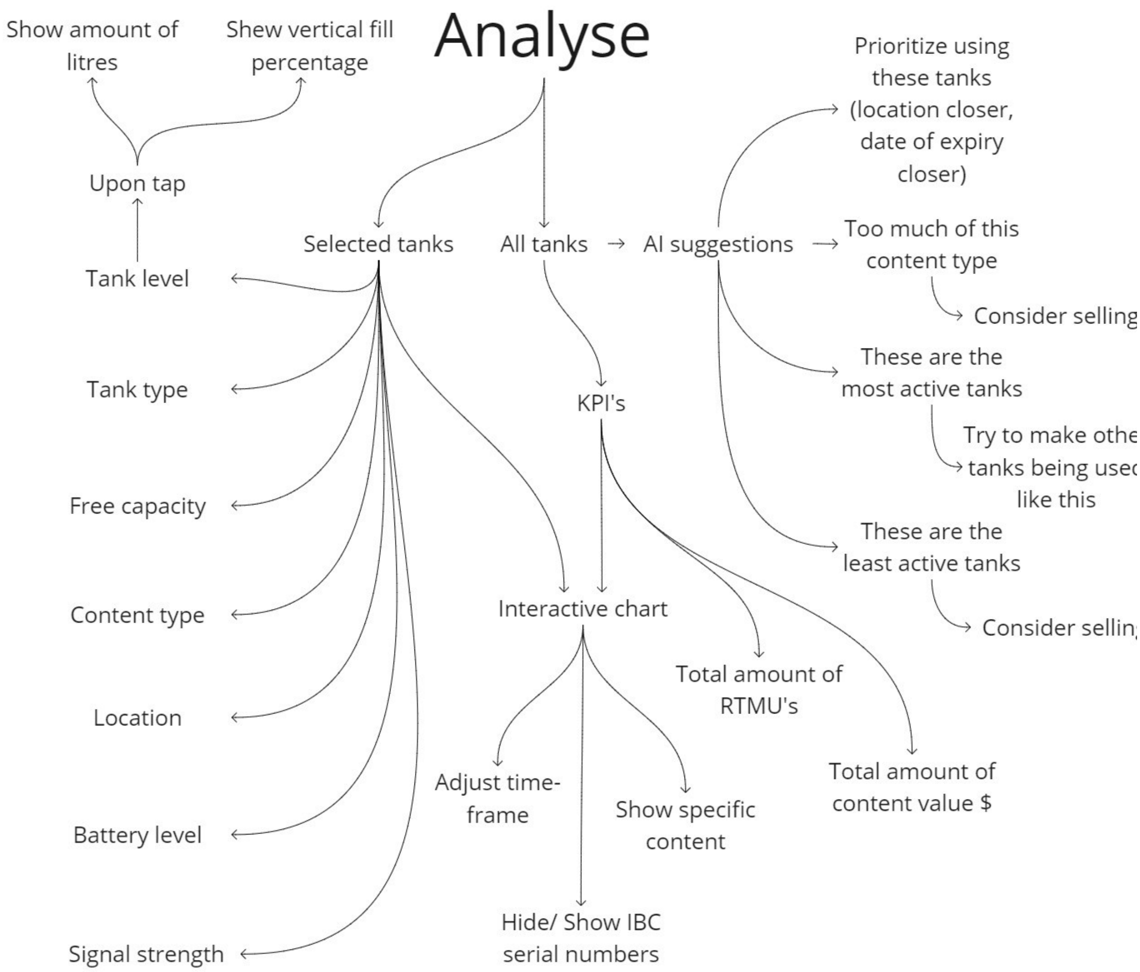

Figure B.2: Part 2 of appendix 2: Function diagram of the Analyse section of the user interface

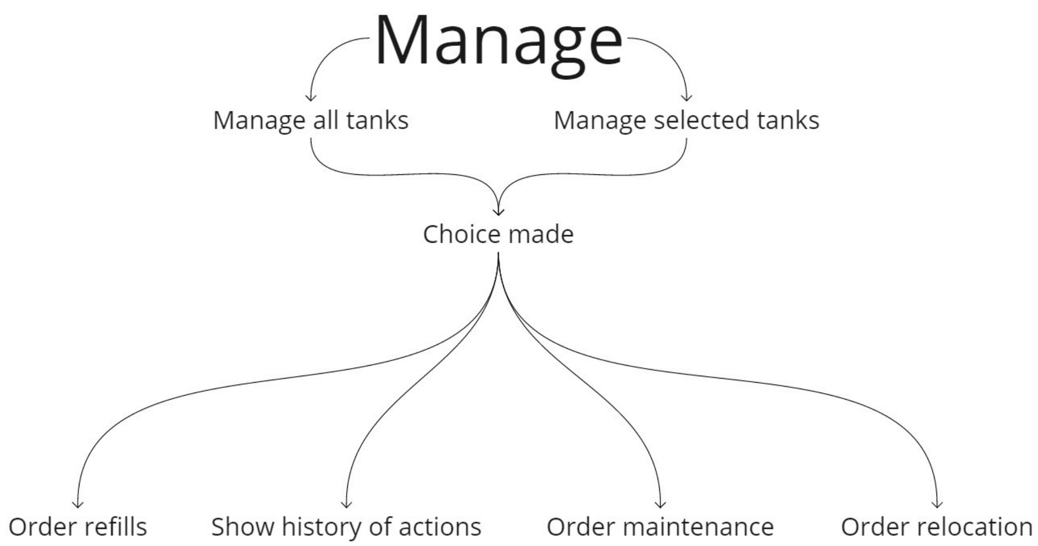

Figure B.3: Part 3 of appendix 2: Function diagram of the Manage section of the user interface

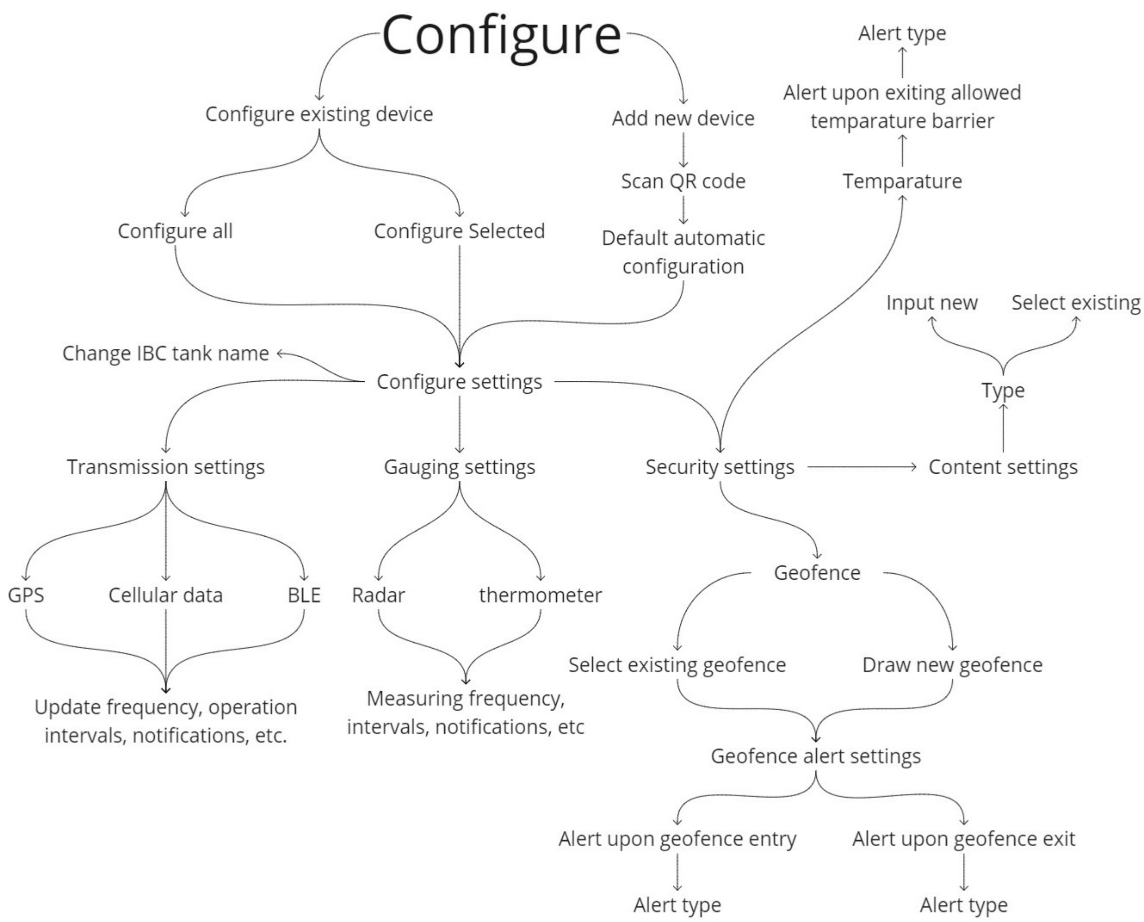

Figure B.4: Part 4 of appendix 2: Function diagram of the configure section of the user interface

C

Appendix 3

In Appendix 3 the interview guide, the collected statements and analysis is presented.

Introduction of us

- Who we are
- What we study
- Thesis project about tracking IBC tanks
- We collect information on how industries are using IBCs in order to develop an user interface
- Anonymity and masking of companies
- Consent of study and recording

Introduction of them

- Name and position
- Time in industry
- Are they aware of IBC use in their organization?
- *Choose questions based on that*
- If there are IBCs but no knowledge – Ask for connections in the end of interview

Introduction on their industry and plant

- What are they producing?
- In what quantity, absolute and in relation to competition
- Do they operate in shifts?
- What real dangers are there if anything goes wrong?
- Do you have any examples?
- Are there moving restrictions for goods on your plant?

Introduction on their system

- How do you track tanks/levels (of any kind) today?
- What is your opinion on your system?
- Can a layman use them, or what is the learning time? Do you need to be an engineer?
- Is this a universal system or specifically design for your application?

Questions on IBCs

- How many do you have at one point?
- How many are full/empty?
- Do you use all content in one run, or need to change them without being fully empty?
- How do you store them? Are they stacked?
- How do you know whats in the middle?
- How do you keep different contents apart?
- Can you think of a production line where you use content from an IBC?
- How is it indicated that content in the tank is running low?
- Can you describe the flow of the new tank from the moment of notification of low levels until the tank is changed?
- What happens to the empty tank? Is there waste?
- If an operator or driver took the wrong tank with the wrong content, is there any way of noticing that?
- What would the consequences be?

D

Appendix 4

In appendix 4 statements and analysis of the interview studies are presented.

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
Business model		
Have no direct opinion on how they would be bought (radar)	Engineer not interested in business model for purchase of RTM product	No fuss business model so that engineers doesn't need to fight purchasers
The general comment was that IBC/barrels were not something they or customers would be super interested in today.	Customers see IBCs as disposable packaging of raw material	
Raw materials Are often ordered at Bulk	IBCs are usually sold many at the same time	
However, the company rents out 15-30 cubic tanks to a number of customers, which today typically includes a radar	Some industries sell their raw material on subscription	System for selling subscriptions
This is then connected in some way to a GSM module that allows someone at Company A to have access to the level to ensure that the customer has enough in the tank.	Uses GSM for radar connectivity	
Thus, Company A (alt customer) has level measurement of the customer's tank which is then read by Company A to plan shipment of product	Plans logistics with radar data	Measurement data need to be able to get in to business system

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
There is potential if they could be owned by Company A altogether, which would also promote that the solution could be sold to more customers	Company would like to own their system and retail it to their customer	Some customer would like to sell their own system
Has any system on any tank, which measures the tanks and sends data via GSM to the supplier who will	Company have subscription raw material with GSM connected level meter	
On their tanks with nitrogen, they have some connected system that the supplier has. They think they bought a package that there is always nitrogen, and then the customer has their level meter on the tank.		
Security		
Imposes requirements on, for example, packaging, labelling, where to place them on the transport	Safety requirements on packaging for hazardous materials. Can not be placed anywhere during transportation	
Leakage, etc., is super important from the packaging.	No leaking is crucial	Leaking detection
Specially certified packaging is used, but at the same time not every single container is checked.	Not every container is inspected	Leaking detection for entire fleet
But they seem to know that there are sensors today to detect	Unaware of leakage detecting technology	Clear marketing, visibility to customers needed
despite safe packaging, they sometimes leak	Approved packaging do sometimes leak	Leaking detection is not useless
Temperature requirements exist for certain products/-transport methods	There are requirements for temperature measurement on some raw materials and some transportation methods	Temperature sensor

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
Some tanks also have GPS transmitters to prevent them from disappearing (however, there are no legal requirements)	GPS is used to make sure tanks does not get stolen or misplaced	GPS tracking and alarms
There are no direct automatic alarms in case of accidents today, but there are routines and protocols for how they should be handled when the call arrives	Currently no automatic alarms for hazardous materials being involved in accidents. There are protocols on how to handle accidents	Automatic connection to first responders could minimize the effects of accidents
sensors were connected to a global alarm system for certain types of hazardous products that alert you if you notice something	There are sensors connected to alarms for some hazardous materials that alert if something is off	
General benefits from this are mainly safety, possibly quality and Customer can see safety benefits from continuous monitoring. Can see monitoring quality as a possible use	Safety can be higher with alarms. Quality can be higher with monitoring	
the biggest challenge is that everything should be Atex rated (solvent is flammable, both zone 1 and zone 2, mostly 1 however) are needed in production (not necessarily outside thereby)	ATEX rated security systems needed for flammables in production, but maybe not in storage.	ATEX rating is crucial for flammables
Looking for temperature/vibration sensors with ATEX – want info. Want to keep track of their mixing machines with relatively high frequency	ATEX rated security system for monitoring vibration and temperature. Monitors some machines with high frequency	Vibration sensors
However, they receive the level value in their System c if the supplier's system does not alarm and they deliver	Customer can see level of chemical that they subscribe to, and can alert supplier if they do not refill	Level data available to both subscriber and supplier

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
(Cyber security) Doesn't seem super critical. Often the supplier seems to have their own sensor that they read, they have no connection to their sensor/System c (4-20 mA)	Do not need to bother about cyber security	Security standards differ
Typically think they are not rated, but could be there at unloading areas	Facility typically not security classed, but maybe receiving logistics area	Not all of facility needs security classing
Do not have an ex-classification, but all products they have after all. Their neighbours are said to have demands for this	Facility not classified for hazard, but raw materials are. Neighbours do mind,	Neighbors mind security to a higher degree than facility
Required to have over filling protection	Some system need over filling protection	Over filling protection is required on oil separation systems
Applications IBC		
Gets some raw materials on IBC, but not much. Mainly from other Company A sites	IBCs are used for raw materials and internal logistics	
Filling raw materials at IBC	Deliver product in IBCs	
However, do not see that customers would typically have to measure the level of these as their goods are often used in larger quantities even if they are shipped on IBC	Do not see their customer needing monitoring of the product they sell	
They have recipes designed based on that size, you usually use an IBC and/or a barrel	IBCs are a standardised packaging	
Has between 100-200 different raw materials for these smaller vessels	100-200 different contents in IBCs on site	Needs to make difference between many different contents
They also fill their finished product on IBC tanks	Deliver product in IBCs	
Those who end up in the IBC go directly to the customer against an order	Only sell in IBCs for pre-orders	

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
It is emptied by lifting by forklift where you open the crane (so it really has to be mobile)	The IBC is carried by a forklift in production. The crane is opened manually	Forklifts need to see information.
Taking things into IBC's, like additives	Buying additives to raw material in IBCs	
Connectivity		
Today, there is an external party that handles wireless communication, which is not considered optimal	2rd party management of wireless communication is not optimal	Owning the communication system is optimal
Generally likes wireless	Wireless is good	Prefers wireless systems
Company B has some preferences around wireless, ban on cloud services, etc.	Wireless is regulated. Cloud is banned	Non wireless, cloud free solution is essential
If they can be from a "standalone" device, they should be okay, like they go to the iPad and then emptied manually via type USB stick to the computer and into the system	Would like to be able to transfer data from mobile unit to computer to avoid wireless transmission	Need option for wired data transfer
Range needs to be >50m	Needs to be able to connect over large areas	Connectivity area needs to be large
forks connected with System A digitally	Their forklifts use a system for logistics orders	Needs to apply with forklift logistics systems
Does not need to be wireless, today goes to a System B system with a red box that warns etc.	Do not require wireless. Visual, red box for warnings	Uses red as a visual warning color.
Use situations		
A typical place was some grease/water separation tank before water was shipped for cleaning (environmental requirements).	Measures on grease separators before sent for cleaning	Needs to work on grease separating systems
some radars on steam formation	Use radars on liquids that steam	Needs to work with steaming products
Most often they are carried out today on a scale. Do not like the scale so much due to calibrated. Dirty and they go wrong	Measures volumes with a scale that has to be calibrated. Create mess and fails sometimes	Less calibration and less messes

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
They have also used volume via pump (DP flow, 400/l per minute), but they are negatively affected by a pump cavorting with high viscosity products	Can use volume pump for low viscosity products	Universal system for all viscosities
as I said, would be willing to measure the emptying of an IBC into the production tank with a handheld radar unit which in turn is connected to the computer system with stock/prescription	Could use a hand held system for measuring the emptying of a tank to production. Could be connected to stock-/recipe system	Handheld system. Connected to recipe system and business system
Sees the possibility of a handheld device that you can use to record how many liters you have left. Perhaps used for betting in the process	Likes to see volume left. Could be use for making batches in process	Visual of volume left
Has a project at G within Europe that is run via City A where you "remove work that does not create value" type manual rounds. Should bring in many sensors to solve this, typically "wireless" sensors.	Could use sensors to decrease manual rounds	Connection to system for rounds do minimize manual labor
There are also deposit tanks for lab samples etc. on unloading	Uses IBCs as deposit for throw away liquids	
Also has an application with salt + water mixture that is more or less working. Today not automated, but deemed "simple" and one could use "simple radar"	Do have manual processes that could be more automatized	System for automation on simple processes

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
The new wireless they are looking at (mainly pressure/temp) will enter the System c for process data. Lubeoil, on the other hand, is a little more into whether they are going into the AMS and not in the control system.	Uses different systems for different raw materials	Out data compatible with different systems
Got tanks for the sewer system. Tanks are buried and in basements. Have alarms on them today, but then they're too late	Use IBCs for oil separating in the sewage system. Only had catastrophe alarms	Alarms on dangerous trends
Could also detect leaks if they can trend	Could use trending data to detect leakage	Trends to detect leakage
Depending on the position it sits, it may end up underwater (groundwater may end up above tank level), today's sitting on a pipe to remove the electronics	Sensor may be under water for prolonged times	Need some IP classification for waterproofing
Raw materials/products		
their paint is like liquid metals (very thick) – heat is needed to keep them afloat	Their product needs heating to be less viscous	Temperature sensors
Probably they don't splash so much (high viscosity) and no foam	some products do not splash due to viscosity, and do not foam	Needs to work with splashing and foaming products
Inventory		
The only check will therefore be 1-2 times per year that you inventory	Checks inventory 1-2 timed a year	
Carry out rounding to check lube oil	Rounding for lube oil	
Think they're manually keeping track of additives	Manual tracking of some raw materials	
For lube oil, you manually check in sieve glass.	Manual tracking of some raw materials trough measuring in glass	System for automatic rounds on lube oil

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	Interpretation	Need
Inventories three times/year with scale. Taking an afternoon.	Counts inventory 3 times a year trough weighing	Radar measuring would decrease the need of moving IBCs while counting inventory
Have visual system on the IBC's to see approximately how much they are	Use a visual system for tracking inventory in IBCs	
Practicalities		
The accuracy they seek is at a litre level	Accuracy in liters	Accuracy in L
They do not go super fast when they fill, take maybe 2-15 minutes.	Filling is slow	Fast/live updates for quicker fills
Typically not stacked. Empty stacks.	Do typically not stack IBCs unless empty	Bird view on IBCs with content could be sufficient in some cases
A few centimetres. So you don't go "dry"	Centimeter accuracy. Need to not run dry	Accuracy in cm. Alarm when nearing empty
Maintenance		
Do not have an automated system for this. However, they wish for	Have no automation on their maintenance	Automatic work orders for maintenance
Perform maintenance of all meters once a year by manual "dipping"	Checks level meters yearly by dipping method	Easy, preferable automatic calibration
Sucks oil layer every 6 months, therefore they have also not received any warnings/alarms	Do not receive alarms from oil separators trough scheduled maintenance	Continuous level measuring could optimize maintenance schedule
Every two weeks, they measure in samples of the wastewater	Regularly confirms that their oil separators work by controlling waste water	Minimize extra work on testing waste water trough leakage monitoring on oil separation
Visuals		
Would like an external display in the truck (type iPad), such displays have in production today	Likes to be able to have displays in forklifts	Forklift system application

Table D.1: Table of statements and interpretations from the case company interviews.

Statement	**Interpretation**	**Need**
At least in System c, but if they could show up in the maintenance system to trigger a work order, they'd be partying.	Getting work orders to other system would be nice	Connection to the system that create work orders for logistics and production
Sees interest in its 4 oil separators (Company C and Company D), 70mm warning, 150mm alarm. Would like to see earlier and see if they go "fast" up	Likes to see trends to manage emptying of tanks	Trend data to see if levels go up too fast. Data in mm
Wishes		**need**
See interest in seeing water/oil measurement, but they become an emulsion	Emulsion between oil and water makes it difficult to see level of oil	Measuring on emulsified oil/water mix

Interview 1

Figure D.1: Analysis of interview 1 part 1.

Figure D.2: Analysis of interview 1 part 2.

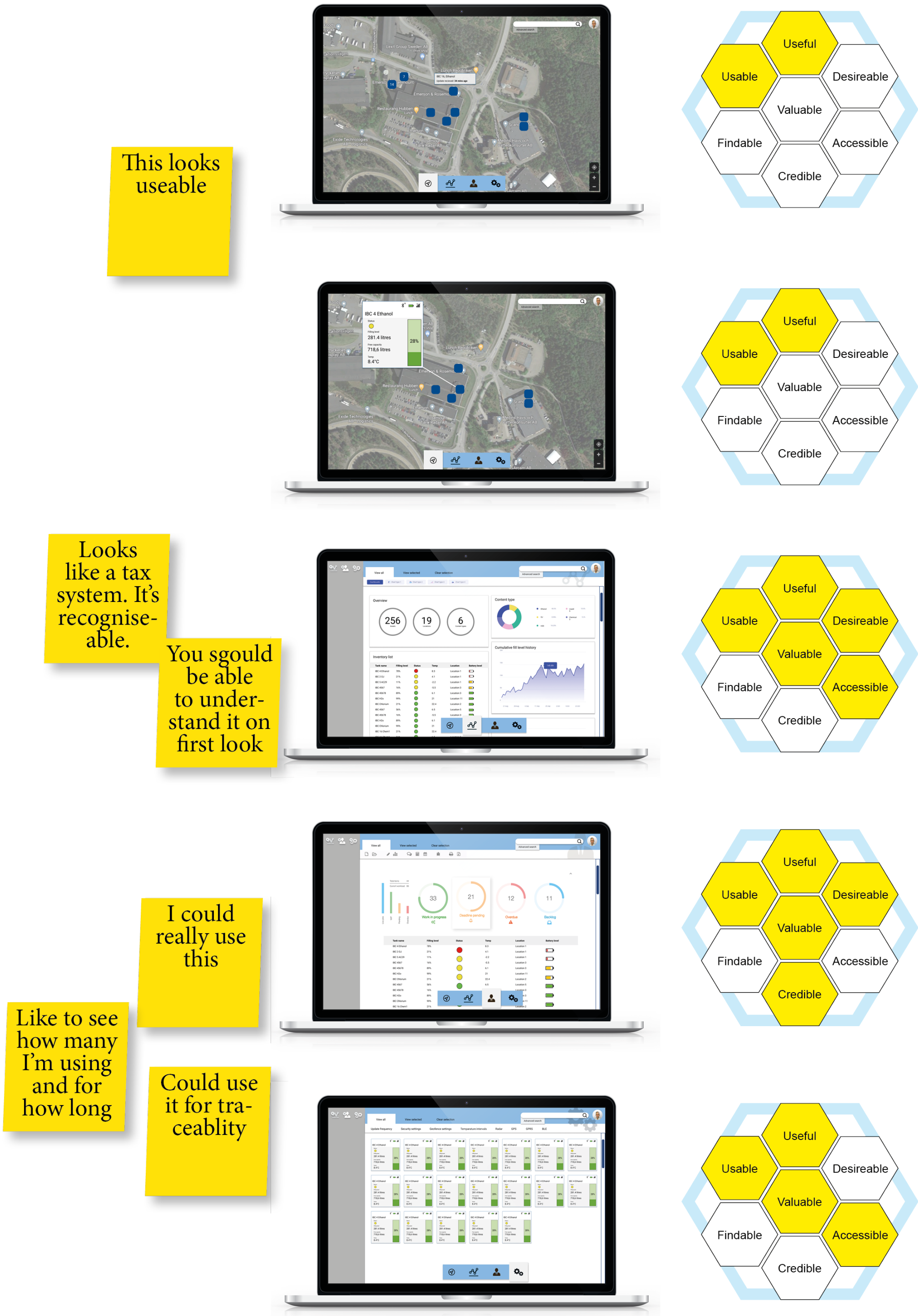

Figure D.3: Analysis of interview 1 part 3.

Interview 2

Figure D.4: Analysis of interview 2 part 1.

Figure D.5: Analysis of interview 2 part 2.

Figure D.6: Analysis of interview 2 part 3.

E

Appendix 5

In appendix 4, the rest of the user testing results can be found, which were not presented in the results chapter of the report due to insufficient space. The first of two parts of results is presented in figure E.1 and the second in figure E.2. The figure include separating lines which run horizontally across the sticky note configuration in order to maintain from which participant the sticky notes have originated from. The utility in this was to confirm that overlapping findings were not coming from the same source subject.

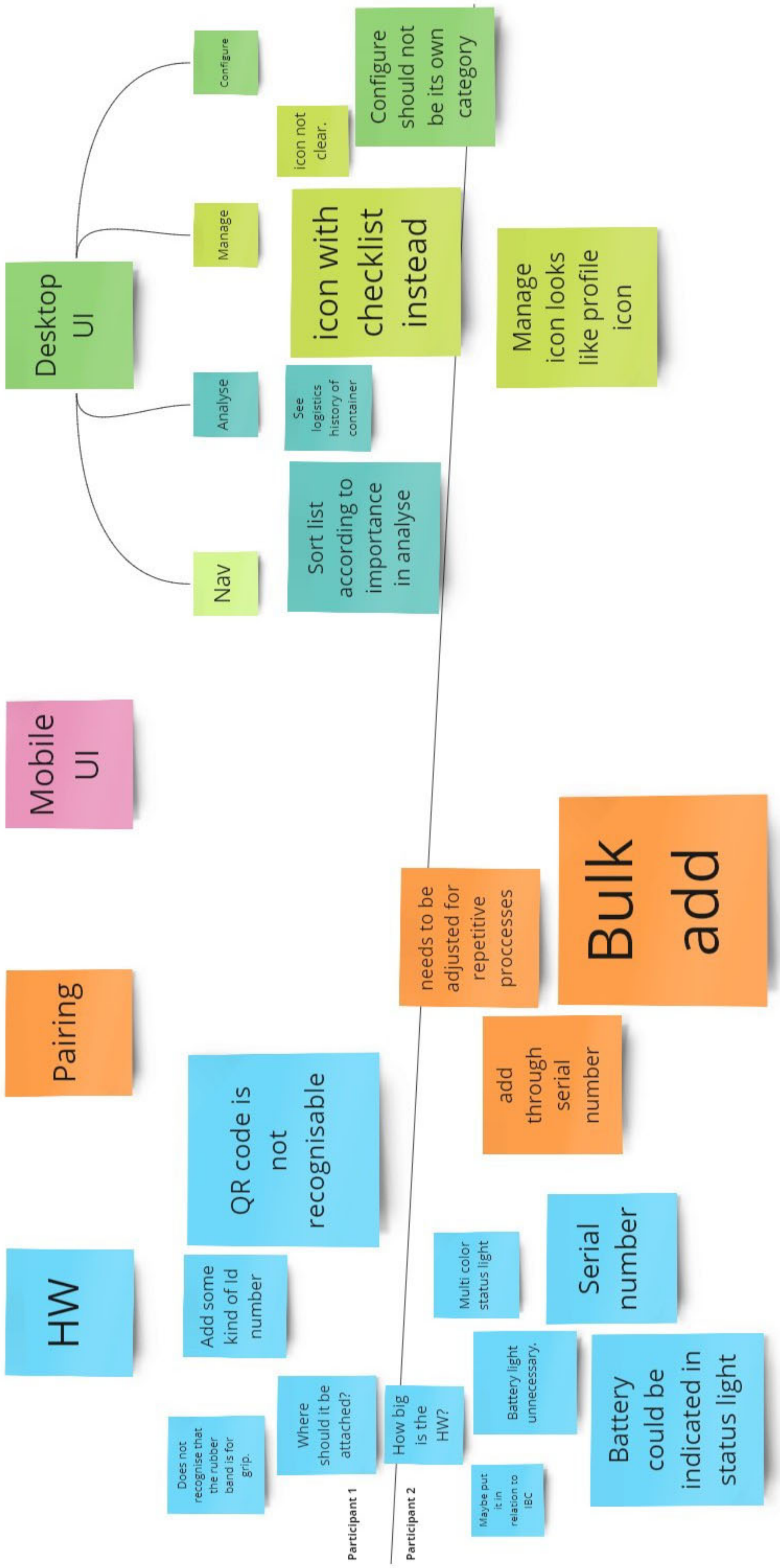

Figure E.1: User testing results part 1 of 2.

Figure E.2: User testing results part 2 of 2.

F

Appendix 6

Appendix 6 contains the full workshop data result which was sorted by the KJ-analysis method. It is presented in figures F.1, F.2 and F.3.

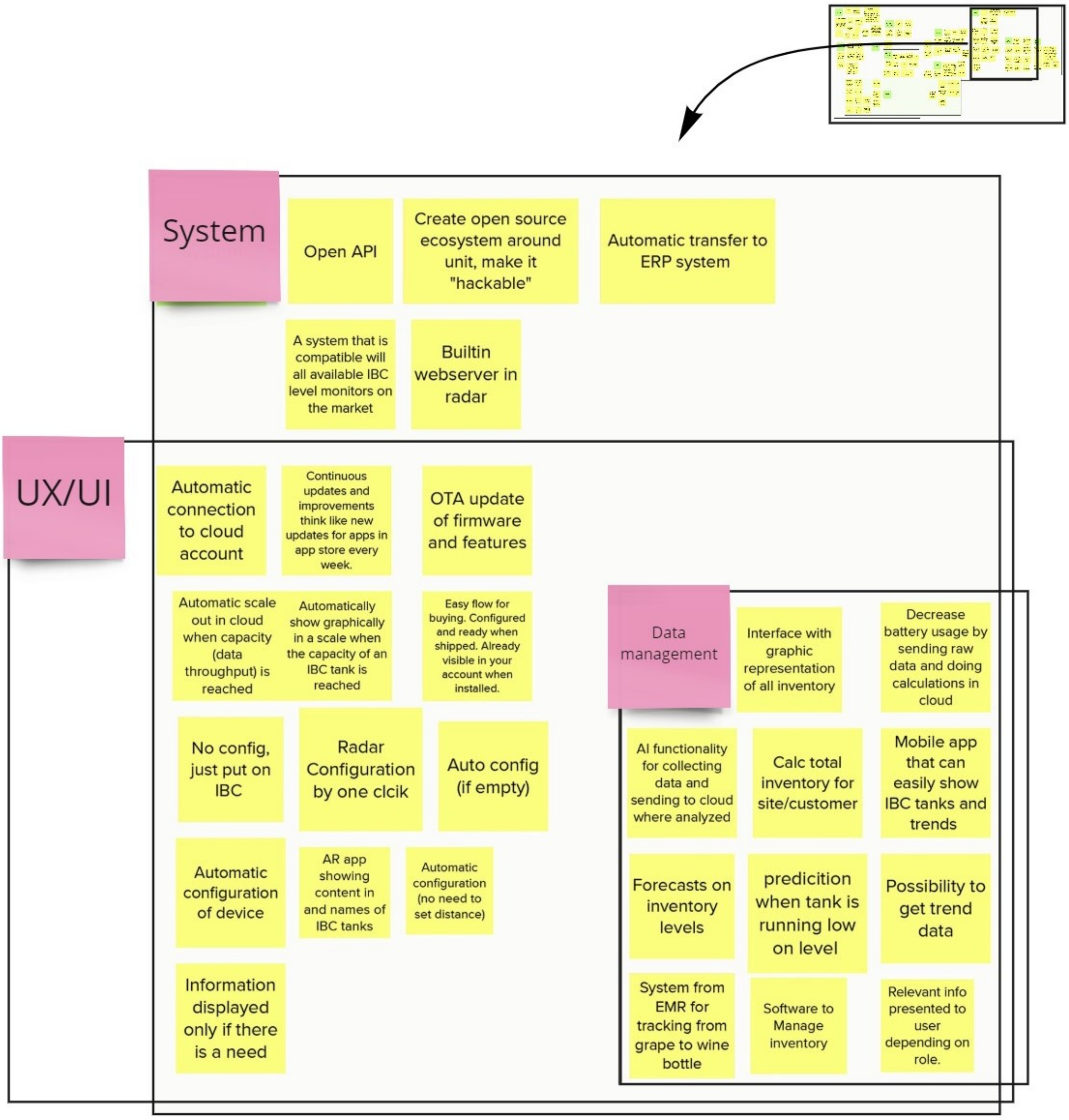

Figure F.1: Workshop results part 1 of 3.

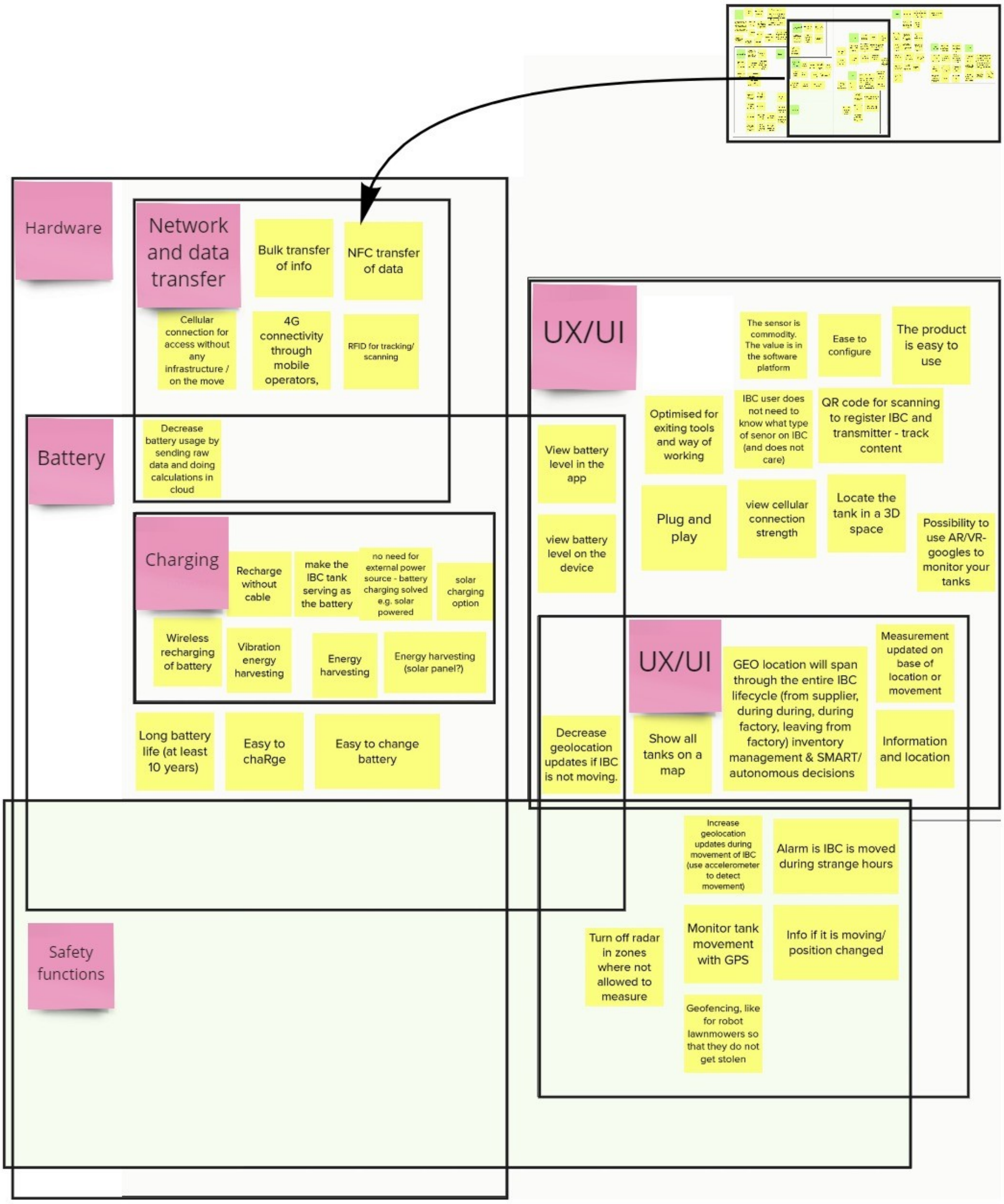

Figure F.2: Workshop results part 2 of 3.

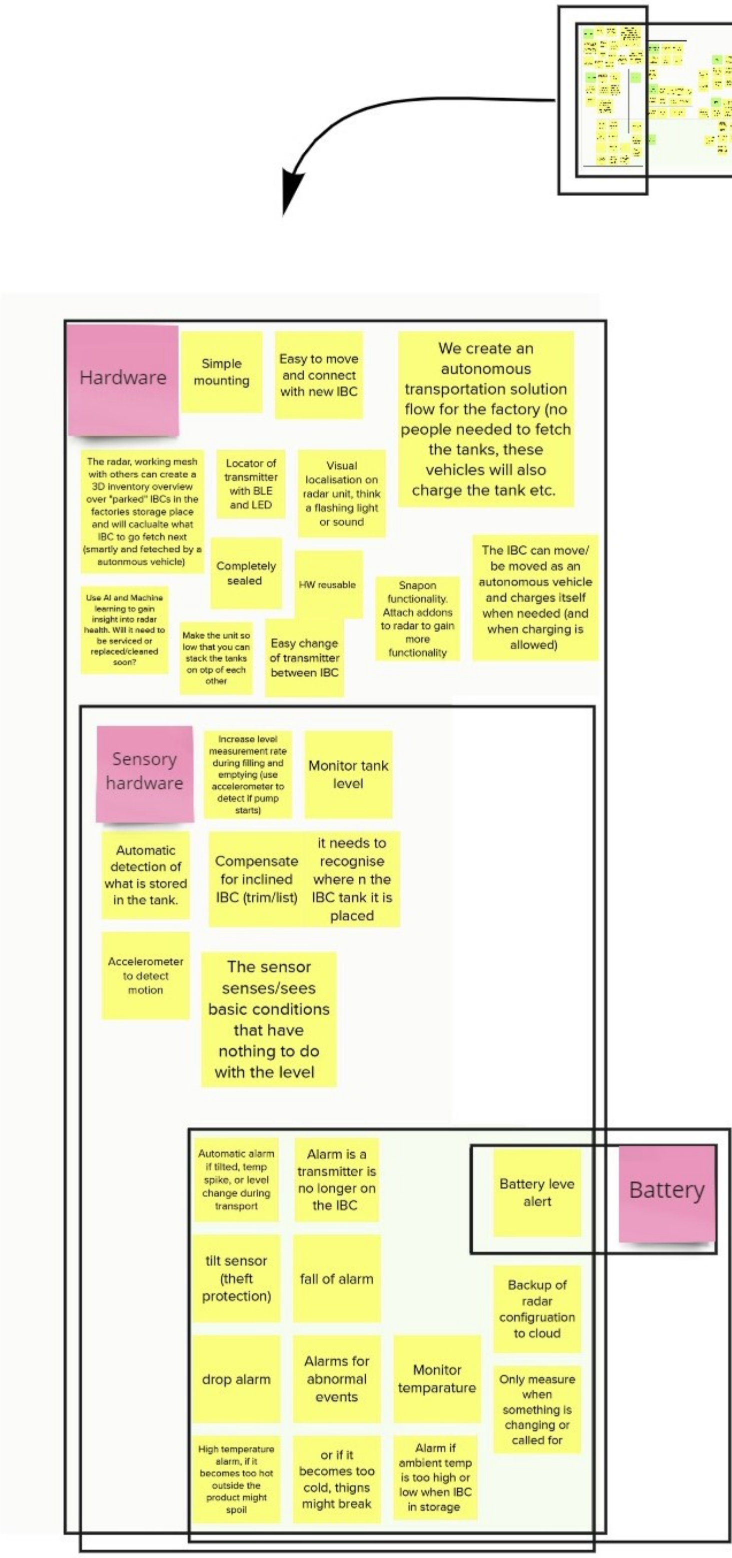

Figure F.3: Workshop results part 3 of 3.

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