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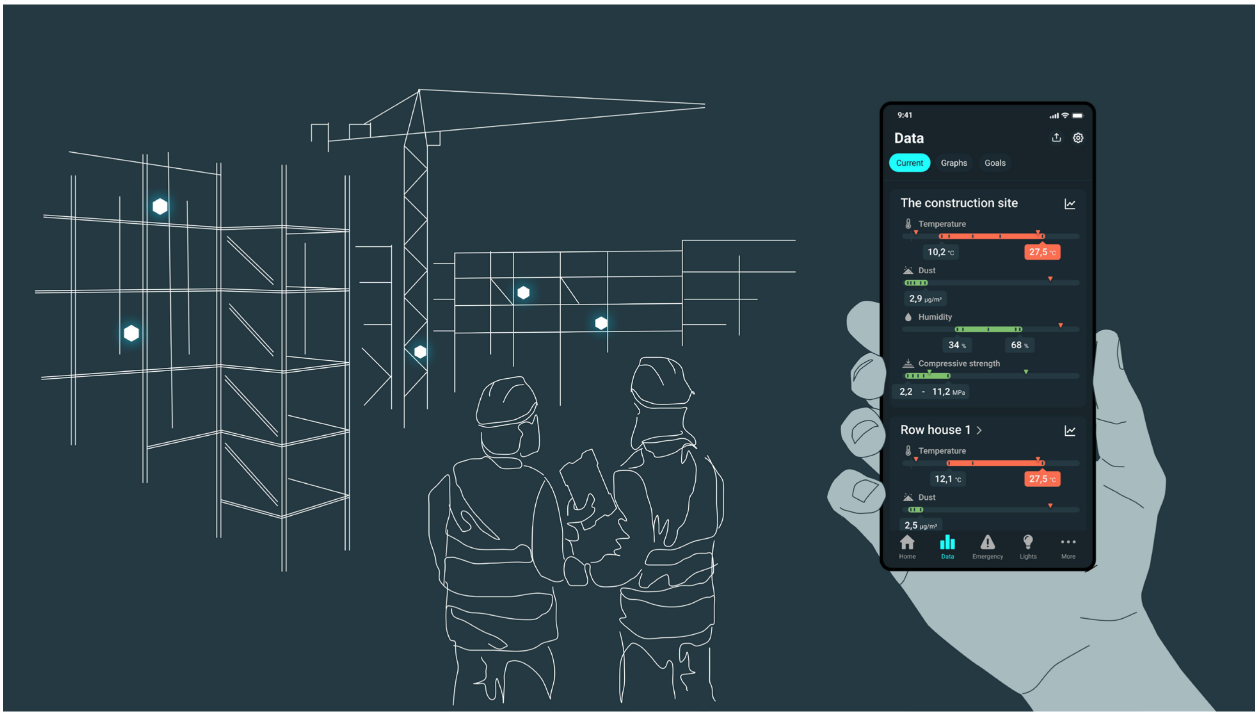

Enabling connected construction sites

User interface design for enhanced situation awareness and usability in a construction application for mobile devices

Master’s thesis in Industrial Design Engineering

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Abstract

Despite the potential for improvements of processes and productivity, the construction industry has undergone low levels of digitization and relatively little research about user experience and interface design in the area has been conducted. This thesis aims to contribute to the area through outlining the specific needs of users in the industry and to suggest how the user interface design of a mobile application can be implemented to aid user acceptance, improve usability and user experience and contribute to generating situation awareness among its users. The development concerns five focus areas (location description, setting up new devices, data visualization, setting up new projects and messaging) of the construction tech company Brinja's app.

Through in-depth interviews with 12 stakeholders, the current processes and user needs in relation to the construction app have been investigated. These have uncovered large variations in the technical systems used and the user needs. To understand these, a number of tasks that need to be supported in the app design have been identified. Digital prototypes of design suggestions for user interfaces have been developed with the research insights as a framework.

Situation awareness on construction sites has been found to be lacking due to difficulties in gaining an overview of processes and spreading safety critical information, despite extensive undertakings to reach out with information. A user interface for a messaging function and a new way of visualizing data is proposed as a remedy. Furthermore, variations in internal systems and resistance to adapt to new solutions and conventions has been found to limit the possibilities for location descriptions within the app to accurately map to the real world and acceptance of new solutions. A data model for location description, that is possible to incorporate into the varying internal systems used at construction sites, is proposed. Furthermore, user interface designs optimized for task completion and acceptance for users without prior experience of setting up devices and projects in Brinja's app have been developed.

Evaluations of the prototypes have indicated high levels of user acceptance and the potential to drastically improve the preconditions for generating situation awareness as well as supporting the users' tasks to increase efficiency. The findings and solutions proposed can also be used as a knowledge framework for future endeavors in the digitization of the construction industry, specifically regarding the development of user interfaces.

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Terminology

Cards (tiles)
A UI element that divides information into groups

Data model - Datamodell
Model of the elements of a data structure and their relationship

Flow - Flöde
A specific way or order of moving through an user interface or process

Guessability
Usability during the first time a user interacts with an interface

Learnability
Usability in relation to learning to use an interface after the first interaction

Mediating object - Medierande object
Object that aids communication by providing context and direction for conversation

Mold - Form
Temporary container for concrete pour

Overlay
A UI design element that lays above an existing page.

QEHS - KMA
Person responsible for quality, environment, health and safety policy

Shoring, shore - Stämp
Temporary support structure for elevated molds and concrete pours

Site manager - Platschef
Manager with the highest overarching responsibility on construction project

Subcontractor - Underentreprenör
Contractor employed by projects responsible construction company

Supervisor - Arbetsledare
Manager with specific defined area of responsibility on construction project

Task conform
Corresponding to or acting to support completion of specific tasks

Usability
Effectiveness, efficiency and satisfaction of a product for a specific user

User experience
A users quality of interaction with a system or interface

User interface - Användargränssnitt
The point of interaction between a human and computer

1. Introduction

This thesis work concerns research and product development in relation to user experience and the user interface design of a mobile application used in construction. In this chapter the background and the aim of the thesis work is introduced.

1.1 Background

Digitization has in many aspects had a huge impact on large parts of the manufacturing industries in recent years. They have seen implementation of new digital tools such as smart sensors, automated digital systems and information technologies that enable new ways of immersing users in processes, control systems and providing decision support (Leviäkangas et al., 2017). This shift can result in overall performance improvements, faster production and increased quality. Consequently, funding and development as well as extensive research in the subject has followed as a means to lead these industries forward through the shift (Oesterreich & Teuteberg, 2016).

While the benefits are obvious, the construction industry which is one of the worlds most impactful industries constituting roughly 10% of GDP in the EU, has seen a comparatively low level of adoption (Leviäkangas et al., 2017; Oesterreich & Teuteberg, 2016; Schönböck et al., 2022). In both the US and EU, the construction industry accounts for the lowest or among the lowest levels of adoption rates of digitization among any sector (Leviäkangas et al., 2017). It is also a sector where research and development accounts for among the lowest levels of investment as a share of net sales, compared to others. Meanwhile, the construction industry has, over the last decades, seen a decline in work productivity as other sectors in manufacturing have almost doubled their productivity (Oesterreich & Teuteberg, 2016). Considering this, there is a need for further developments and research.

However, contrary to some assumptions digitization itself is not correlated with the benefits of increased productivity. It requires strategic implementation and an extensive understanding of needs (Leviäkangas et al., 2017). While one field within construction technology, that of building information modeling, has seen extensive research into adoption and needs (Zhang et al., 2020), other fields lag behind. Specifically, in the current state of low digitization, where humans are still at the center of all processes, there is a pressing need for development of new solutions for human-machine interaction that can meet the specific challenges of the industry (Schönböck et al., 2022).

These challenges include a complexity with many actors that are connected in loosely defined structures that are difficult to organize. Construction also suffers from low specification of processes since all projects are different and require individual solutions. Furthermore, the construction industry is notoriously anchored in existing cultures with a resistance to change (Oesterreich & Teuteberg, 2016). These challenges introduce a need for generating situation awareness and communicating information efficiently through organizational barriers. Furthermore the inter-project variations creates a need for detailed real time information regarding the specifics of the project at hand as a means to adapt processes and decision making to the real world. Additionally, all implementations of digitized solutions need to take careful consideration of user acceptance to ease transitions even within strong cultural resistance.

In this report, these issues will be covered in relation to human machine interaction and the user experience design of an app used in construction. The app is one part of the product offering of Brinja. Brinja is a Software-as-a-Service company operating in the construction industry. They offer small devices that are connected to their smartphone app. Placing these devices across a construction site will provide the customers with data on pollution, temperature, humidity and noise among other things, which is displayed in the users' phones. Furthermore they offer additional services incorporated into the app, such as light-control at the sites, concrete-measuring and evacuation-systems. Brinja describe themselves as an innovative tech-company that is dedicated and passionate in improving the safety, efficiency, and sustainability at construction sites. Brinja has served customers such as PEAB, NCC, and Skanska. (Brinja, n.d.)

As a company operating in an industry with a relative lack of previous research and standards regarding the development of digital solutions in general and user interfaces in particular, there is a strong need for user research and human centered design. From Brinja's fast development process emerges a need to design new functions and develop existing ones that meet the diverse user requirements, accommodates the aforementioned challenges of the industry and effectively implements user interface design as a means to drive adoption and enhance user experience.

One such development constitutes a coming shift in Brinja's product offering where devices will partly be sold over the counter as opposed to through internal sales channels. This introduces a need for the end users to start projects and install devices on their own, a task which has until now been performed by employees of Brinja. Furthermore, a potential messaging function has been considered as a new product offering, requiring insights regarding the need for such a function and how it can be implemented. Lastly, data visualization, a major part of Brinja's product offering can benefit from adaptations to user needs for added value creation as more and more is learned about how it is used among new and different customer groups. These focus areas will be investigated in this thesis.

1.2 Aim

The overarching aim of the thesis work is to investigate the needs of the app's users and suggest design solutions for Brinja's app with a focus on achieving high usability and a good user experience in the five different focus areas that are studied. These areas are:

- Location description, how locations are described and set for devices
- Set up of new device, how devices are added to the app
- Data visualization, how data gathered by sensors are presented
- Set up of new project, how the user can set up new projects by themselves
- Messages, a new feature of how information can be transferred at construction sites between its workers with the help of the app

For location description, the research aims to investigate existing naming schemes for construction locations and how a data model can be formulated to support both understanding among users through mapping with mental models and the task of assigning locations to devices. The focus area of setting up new devices builds on these findings and aims to establish the needs of end users in relation to independently and without prior knowledge being able to efficiently install devices. Furthermore it is also aimed to establish the needs of expert users. A design suggestion for a user interface design that supports this task for both the end users and Brinja's expert users will be developed.

For data visualization, the research aims to establish how data is currently used at construction sites and how the app usage connects with existing processes as well as how the data visualizations can be improved to better support situation awareness and task performance. A design suggestion that implements these improvements while supporting the vast breath of needs, competences and experience levels present in construction will be developed.

Set up of a new project is a focus area that aims to enable end users to successfully set up projects themselves while providing them with a positive initial experience and lowering the threshold to start using the app. The focus area of messages aims to establish if and in which form a messaging function is requested and what purpose and value such a function would provide. For both of these focus areas a design suggestion that implements the findings from research and provides high user acceptance of the new functionality will be developed.

2. Theoretical framework

During this thesis work, established theory has been utilized as a means to create understanding of the current state and underlying mechanisms of operation and as a tool for product development. This chapter presents the theoretical framework for this thesis work. It first introduces the context of a construction site and Brinja's ecosystem. Furthermore, it includes theory in the areas of cognitive ergonomics, usability as well as technology adoption and acceptance.

2.1 The Context

The context of a construction site and the functionality of Brinja's product offering are relatively complex and require some introduction. Information necessary for understanding the concepts highlighted in this thesis work and decisions taken as a consequence are presented in this section. It first covers the construction site and then the Brinja ecosystem and how it is incorporated into the processes in construction.

2.1.1 The Construction site

At the construction site there are many different people with different roles. A site manager is responsible for the entire construction project, overseeing the planning, budget and progress while maintaining communication with people at the site and the client of the project. The construction workers are performing the physical labor and the operation of machines at the site. They get their instructions from their supervisors who are intermediaries between the site manager and the construction workers. The supervisors are responsible for occurring problems at the site (eSUB, n.d.). A person working with QEHS (Quality, environment, health and safety policies) is responsible for ensuring quality, environmental performance and health & safety of employees at the site (4C Consulting, 2022). Furthermore there are often subcontractors such as electricians and painters who are called in when needed, consequently there are often a lot of new people at the site. Since 2016 it is mandatory for construction companies to use an electronic personnel ledger to keep track of everyone who enters and leaves the site (ID06, n.d.).

A fundamental process at construction sites is the concrete casting and hardening process. To understand the results of the focus area of data visualization this process requires specific knowledge which is covered in depth in this section.
The development of the concrete's strength is dependent on the temperature and humidity, resulting in a logarithmic growth spanning over multiple decades. However, most of the hardening happens over the first month of the hardening process.
The concrete is cast into temporary molds which can be removed after hardening. Temporary support structures referred to as shoring are sometimes used to hold the molds until the concrete reaches a strength where it can support itself. The strenght is estimated using a concrete model where the compressive strength is retrieved as a function of the concrete's internal temperature. When concrete hardens its internal temperature rises in a consistent manner which can be used to follow its hardening development. Since the temperature and humidity impact the development of concrete, the environment and the time of the year influences the hardening process. During cold weather, heaters (e.g. diesel heaters) are used to decrease the hardening time and to ascertain that the concrete temperature never drops below zero degrees centigrade before it has hardened, in which case the concrete is ruined. Concrete, steel and other materials and processes within construction makes the industry a major contributor to emissions of greenhouse gasses. As of 2019, 21% of the total greenhouse gasses in Sweden came from the construction industry and the decrease of the industry's total greenhouse emissions has stagnated during the past decade (Boverket, 2021).

2.1.2 The Brinja Ecosystem

Tackling the environmental impact of construction as well as providing support for the complex processes available and increasing safety through connectivity and overview are central aspects of the Brinja ecosystem. Brinja offers several products in the form of physical devices that are installed on the construction site. The main devices are

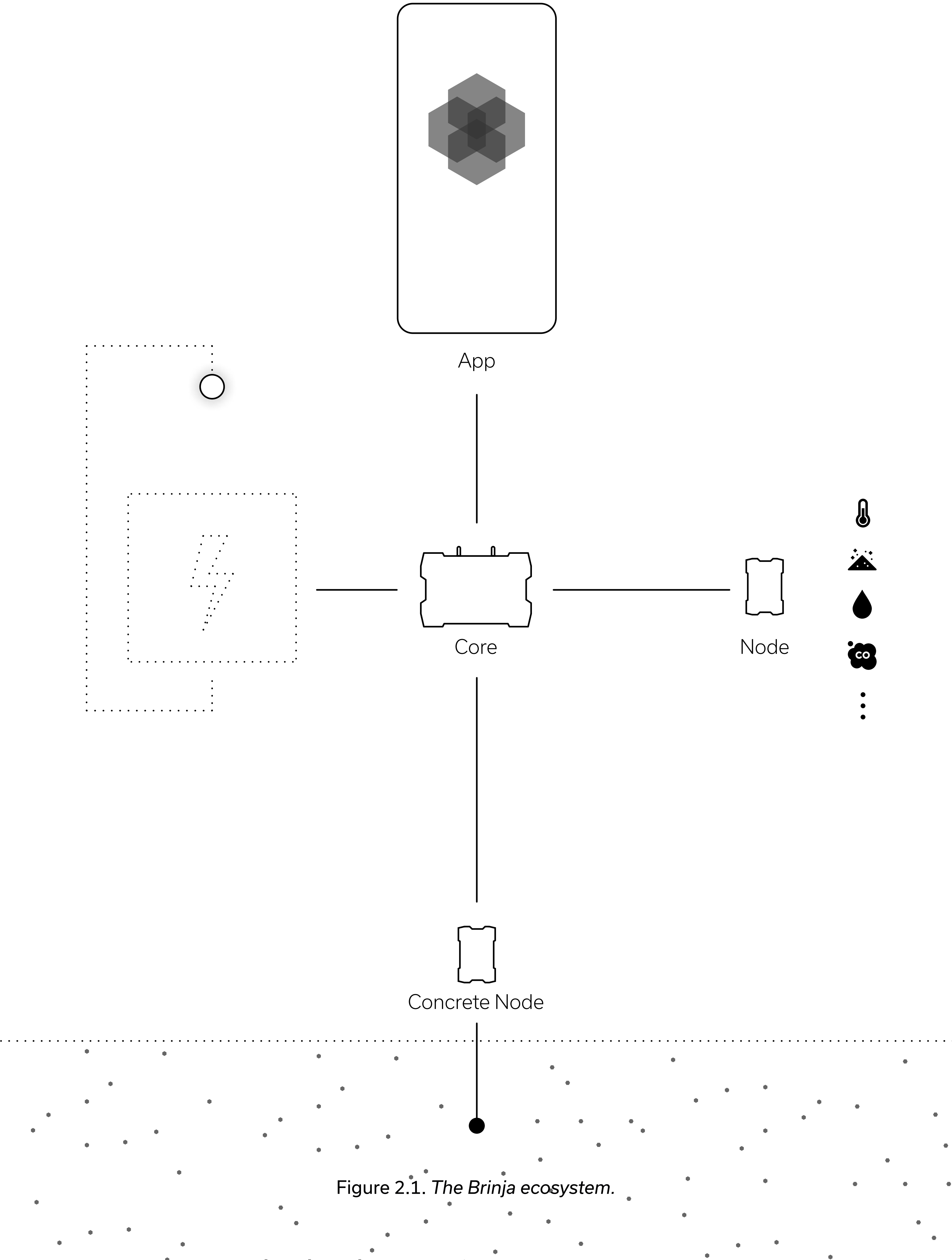

Figure 2.1. *The Brinja ecosystem.*

called Cores. These are connected to the internet to allow for connectivity with the app. The Cores can have construction lights such as LED strips installed to them, in which case they allow for light control through the app and evacuation services in the form of alarms and emergency lighting. Smaller devices called Nodes can be wirelessly connected to the Cores. Nodes contain a multitude of sensors which allows them to collect various forms of data from the site. Each device has a unique UID number which is used to identify which one it is. Through the connected Cores this data can be forwarded and retrieved in the app where it is presented. The Brinja app is structured projectwise where each construction site has its own project to which the site's workers have access. Concrete Nodes are a special type of sensor device which is installed into the concrete during casting. These measure the internal temperature of the concrete which allows for compressive strength calculations. At the start of the projects the devices are installed by Brinja employees. During installation each device is set up in the app by assigning it a location in the form of house part and floor as well as a label which becomes the device's name in the app. The Brinja ecosystem is visualized in figure 2.1.

The app is the main interaction point with Brinja's services for construction workers. It has a structure consisting of five main tabs; home, data, emergency, lights and more. As of the start of the project the home tab presents some information about the project in general (left image in figure 2.2) and includes a plus-button through which the user can add new users and devices to the project and join other projects. The data tab presents average data from the different house parts (center image in figure 2.2) and allows you to see more detailed data visualization from floors and individual devices by going deeper into the interface structure. At the deepest level, graphs showing data from devices over time can be accessed with the ability to filter which devices are shown (right image in figure 2.2). The user can also set data thresholds that trigger a notification if breached. These settings are accessed under more where the user also manages their projects and devices and where Brinja employees access the setup of new devices.

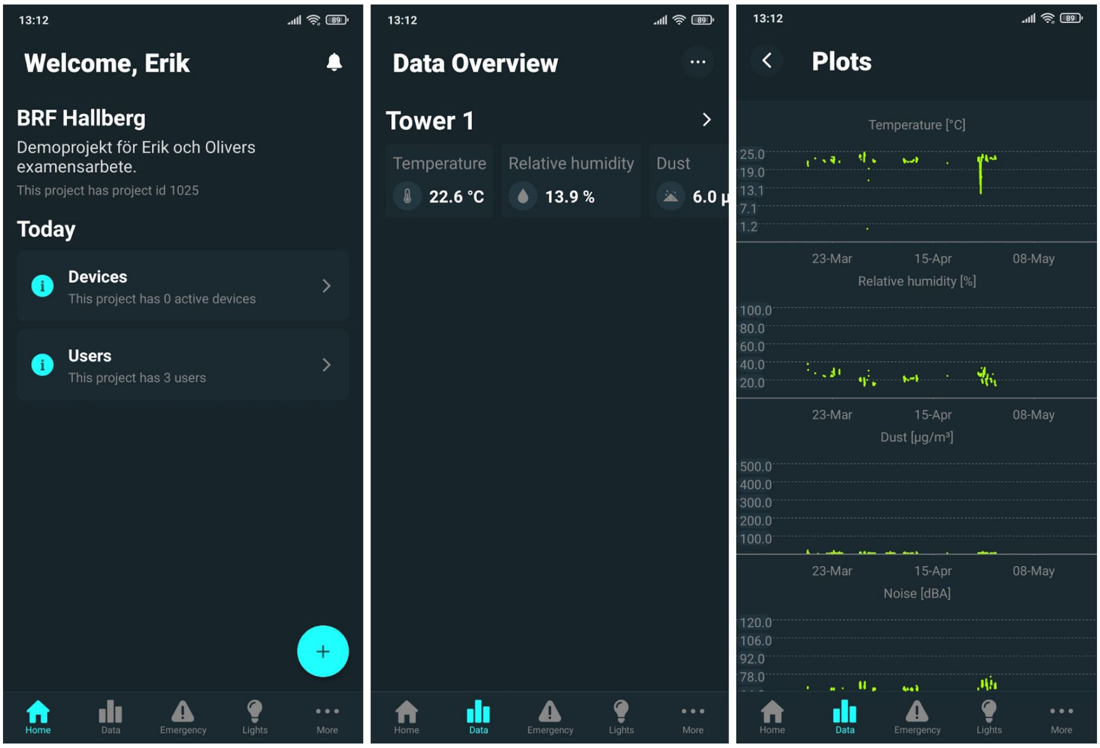

Figure 2.2. *The Brinja app today.*

2.2 Cognitive ergonomics

The work on a construction site, specifically in relation to usage of applications such as Brinja's, requires extensive cognitive processing and decision making. To generate an understanding of these mechanisms and appropriately design for them, theories within the field of cognitive ergonomics have been utilized. Cognitive ergonomics is a field of study that takes reference in human cognition and applies it within human computer interaction. It is concerned with how computers can aid the cognitive processes of people (Waern, 1988) and more specifically how user interfaces can be designed to support the user in handling information (RISE, n.d.). This section will cover theory relating to cognitive ergonomics such as distributed cognition, cognitive artifacts, Normans theory on the psychology of artifacts, situation awareness and automation bias.

2.2.1 Distributed cognition

Since Cognitive ergonomics is concerned with human cognition in the context of complex interaction with other entities, it is important to first create a foundation for understanding the characteristics of human cognition in interactive systems. The theory of distributed cognition presents a perspective on cognition that broadens the concept beyond the confinements of a single human being. It is different from more traditional cognitive theories in that the system boundary is broadened to include processes with functional interdependencies even if they extend beyond a person, e.g. processes between several people and interactions with material objects. It is also different in that it includes mechanisms and manipulations of objects beyond those taking place in the brain, e.g. changing and reading states of an interface. It is therefore suitable for discerning and understanding the complexities of modern human-computer interaction (Hollan et al., 2000).

Three different types of distributed cognition can occur:

Social distribution
In the same way cognitive processes in the mind of a person encompass a flow of information between different entities of the brain, a group of people can have an exchange of information between the different entities of the group. This leads them to act on the information of each other to perform as one large cognitive system.

Material distribution
Instead of considering materials in our environments as stimuli that impact an internal cognitive system, those materials are considered an integrated part of the cognitive system. They are a part of how a person thinks, interprets and acts. E.g. pilots understand the world partly through the material objects, the interface, in the cockpit. The position of thrust and landing gear levers, altitude gauge and switches are part of the cognitive process.

Temporal distribution
Cognitive processes can be distributed in time. An aspect of this is the social or material storage of information for later use in cognitive processes. This temporal distribution is particularly evident in highly distributed cognitive systems involving people, materials and environments, where a cognitive process can be embodied in either of these units and stored for later.

A field of study that makes use of distributed cognition is that of representations. These have traditionally been seen as a symbol depicting or representing another thing, the symbol and the other thing being two separate entities. However, Hollan et al. (2000) argue that these two entities can become intertwined to a degree where people's interpretations can shift between consisting of the symbol itself and the thing it represents. E.g. A fisherman's cognitive process can incorporate a spot on a sonar display and a group of fish in the water interchangeably; there is no distinction between the representation of fish on the sonar and the actual fish in the water. Hence, it can be assumed that an accurate interpretation of the representation is vital for an accurate understanding of the real world.

2.2.2 Cognitive artifacts

Since cognitive processing can be distributed between a human and a material object to a degree where the object becomes an incorporated part of the representation and processing of information, understanding the characteristics of the object or artifact and its interaction becomes a major concern. Cognitive artifacts can be defined as "an artificial device designed to maintain, display, or operate upon information in order to serve a representational purpose" (Norman, 1992). They are artifacts designed to contribute to cognitive tasks (Fasoli, 2018). By this definition a user interface is a cognitive artifact in itself (Norman, 1992).

Norman (1992) argues that if a cognitive artifact is to support the cognitive process of a human it must allow for both aspects of a person's processing system, namely evaluation and execution. It can support these either separately by having one feedback device and one input device or it can use one system for both purposes, in which case the same device allows you to both input and read state. The feedback is particularly important for social systems with several users. If one user can change the state it is essential that other users are made aware of both the action of that member and the actual state of the environment after the change.

Feedback must consist of three kinds of information to fully verify the completion of an action (Norman, 1992). The first one is confirmation of the act itself, i.e. verification of the correct input action by the user. This should according to Norman (1992) be provided immediately. The second is confirmation of intermediate results, that the correct signal was forwarded to the device operating upon the action. The third is confirmation of final outcome, i.e. the state reached (or not reached) as a result of the action. Norman (1992) argues that the final outcome can take time to reach and that this feedback item is therefore the most difficult to provide clearly and in reasonable time, although arguably the most important item.

2.2.3 Norman's theory on the psychology of artifacts

With the basic information transfer between a cognitive artifact and a human laid out, there is a need to further investigate the factors that impact this interplay in order to understand how properties of the artifact but also the user impacts the interaction. Norman (2013) presents five psychological aspects that designers should keep in mind when designing products. Through consideration to these, the products will be better understood by the user in what it does, how it works, and what operations are possible leading to an improved user experience. These aspects are the following:

Mental models
Mental models are conceptual ideas people create in their minds of themselves, others, objects they interact with and the world around them. What forms these concepts are experience, training, and instructions. The purpose of the mental models are to help people understand the world and guide people to achieving one's goals. These models are not universal and differ from other people's models.

Knowledge in the head and in the world
Knowledge in the head refers to the existing knowledge stored in the user's head on how to interact with certain products or interfaces. This knowledge resembles mental models in the way that it is highly individual and can change over time. Knowledge in the world is referring to the information that the user can derive from the world around and utilize as knowledge in order to use a product or an interface.

Affordance
Affordance is what a user with a set of capabilities can do with an object. When an object can be used in a certain way by a specific user it affords that usage. For example, a glass affords drinking for users who are able to drink from it. By taking the properties of the object and the capabilities of the person into account, the affordance is the relationship that these aspects form that determines how the object can be used.

Constraints
Aspects in the user interface that steers the usage by disallowing the user to perform certain actions, often with the purpose to minimize use errors.

Mapping
The concept of the relation between the inputs of the user interface to the outputs in the real world. This can be used to design the controls to correspond respectively to the objects it affects.

2.2.4 Situation awareness
The previous subsections establish that the system consisting of a human and a cognitive artifact functions through information transfer between the two. In the contexts of Brinja's app a major component of this transfer is constituted by information intended for generating situation awareness. Situation awareness refers to the concept of users being aware of their surroundings and environment of importance for the specific task or goal they are aiming to achieve (Endsley & Jones, 2004). It incorporates the perception of information of importance, the comprehension of that information and the projection of that information in the future, i.e. the creation of a mental model of future status based on the comprehension of current information and status. Building upon the theory of Situation awareness, Endsley & Jones (2004) presents 8 principles of designing for improving the user's situation awareness.

Principle 1: Organize information around goals
The user should be presented with information needed for accomplishing their goals, instead of a technology-oriented presentation where the information is based on the technical system behind the interface.

Principle 2: Present information on the current status directly
Provide the user with information about the current status directly to the user without any extra steps needed, such as underlying calculations, in order to support the comprehension of current status.

Principle 3: Provide assistance for projections of future states
Projecting the future states of a system is a difficult task for the user since there are many unknown factors playing in. This is especially true for less experienced users who do not yet have a well developed mental model. Having a system that supports the user in projecting the future status is consequently important.

Principle 4: Support global situation awareness
Global situation awareness, meaning a high level overview of the system should always be provided. Interfaces that restrict the user from accessing information through directing focus to a subset of information contribute to narrowing down the user's attention and should therefore be avoided. Simultaneously, specific information required to accomplish the user's current goal should be provided.

Principle 5: Support trade-offs between goal-driven and data-driven processing
The first principle of designing around operator goals will support goal driven processes while the fourth principle of supporting global situation awareness supports data-driven processes. Here, a trade-off needs to be done, and balancing the two processing types is crucial. An example of this can be to initiate a data-driven process by directing the user's focus on more urgent high priority tasks when needed. Utilizing cues to steer the attention of the user to critical tasks is recommended.

Principle 6: Utilize cues to activate mental models
Mental models are a key aspect for achieving a high situation awareness in complicated systems. Therefore, one should determine where it is critical to use cues in order to be able to activate these mental models. Thereafter, implement these cues into the interface in order to support the user.

Principle 7: Take advantage of parallel processing capabilities
When operating in complex systems it is important to be able to share the attention between multiple tasks. Situation awareness can be improved when the system supports parallel information processes. Since one sensory input can only take in a limited amount of information, the system can be designed to support other information processes as well in order to increase the amount of information taken in by the user. For example, the system can use both visual and auditory information.

Principle 8: Use information filtering carefully
Consider filtering and reducing the amount of information presented to the user to prevent an overload. By only showing the necessary information to the user the Situation awareness is benefitted. However it is critical to be careful when filtering information. First, removing information will decrease global situation awareness. Second, users must be able to plan ahead and be aware of what is to come, so only showing the current relevant information can harm future Situation awareness. Third, different operators might demand different information in order to form their Situation awareness, consequently only presenting subsets of information can reduce Situation awareness for

some users. To summarize, present the user with clear and easy to process information, where the user can choose what information to look at and when. This will allow for a maintained Situation awareness both in regard to understanding the present and the future states of the system.

In teams the concept of team situation awareness can be applied. This encompasses a number of additional considerations, but it is important to design for individual situation awareness among the team members first (Endsley & Jones, 2004). Situation awareness always exists in individual members only, there is no universal situation awareness for the whole team. However, there are specific requirements on situation awareness in teams as different team members need different situation awareness to perform their individual tasks. In this stride to perform their individual tasks they may need to transfer data, comprehension and projections between each other.

Team situation awareness can be achieved through universal access to the same information or communication to acquire information from each other. Effective team working incorporates forming a shared picture of a problem before pursuing a solution. This coordination and mutual problem solving is effective in assuring accurate judgment of a situation, but it is also highly dependent on the ability to form a team situation awareness for example through free and abundant communication (Endsley & Jones, 2004).

2.2.5 Automation bias

The generation of situation awareness ultimately enables users to make informed decisions about actions to take in order to impact the current situation. This means that the way users interpret the current situation impacts which decisions are made. The representation or information provided by the user interface thus directly influences decision making, requiring careful consideration to how the actual design can positively or negatively steer the user. A decision support system is a type of technology in which the operator of the machine is aided in their decision making process by being provided with advice, enhanced information, prompts, and/or alerts to make more accurate decisions in their work (Goddard et al., 2012).

Goddard et al. (2012) describes automation bias (AB) as the tendency to be over reliant on automated systems. Something that can occur when automated systems are used to support operators in making decisions and taking actions. Although research shows that overall performance increases through this type of support systems, there is a drawback as automation bias can occur. At the core of the problem is the fact that these systems are from time to time incorrect in their judgements. If an automated support system opposes the operator's initial decision they may become tempted to change their correct decision to an incorrect one. Not only can AB be manifested in errors of execution when provided with incorrect advice, but can also occur when the operator fails to act because the system does not prompt them to.

The risk of AB can be decreased in numerous ways. One way is to make users better aware of the reasoning process of the system. Another way is to increase the sense of operator accountability, which can increase vigilance and as a result decrease AB. There are also ways to design for decreased risk of AB. Displaying the advice in a less prominent location on the screen might decrease AB.

Formulating the system's suggestion as supporting information rather than commands can also decrease AB as commanding advice is more likely to be followed in situations of stress since it removes a step of the decision making process (Goddard et al., 2012).

2.3 Usability

Supporting the cognitive processes of users creates preconditions for a usable interface. However, to ascertain overall qualitative interaction and effective support of tasks, both within the complex context of construction and within the confinements of the existing app, theory within the field of usability has been applied. Usability is to which extent a specific user can use a product with effectiveness, efficiency and satisfaction in a specific context. Effectiveness covers if the user achieves the intended goals. Efficiency concerns the resources needed to achieve the goals. These resources can include time and effort. Lastly, the theory covers how satisfied the user is with the experience of using the product (International Organization for Standardization [ISO], 2018). In corporate settings with prescribed use, usability is directly correlated with employee productivity (Nielsen, 2012). In the setting of a construction site with limited time to learn and perform tasks, strict resource limitations and chain reactions as a result of delays, ensuring high usability becomes a vital part of the user interface design. This section covers theories in the area of usability, including principles of usable design, Podmajersky's editing process for UX writing and semantic interaction design.

2.3.1 Principles of usable design

Some general characteristics can be connected to high usability. As an overarching framework for achieving this, Jordan (1998) presents 10 principles of usable design. During this thesis work, these have been pursued as a means for achieving designs which have an overall high level of usability in the specific context and use. The 10 principles are the following:

1. Consistency
Consistency means that similar tasks within the user interface should be solved in similar ways.

2. Compatibility
Compatibility means that tasks within the user interface should be solved in a way that the users expect them to be solved. Expectations that are based on the user's experience of similar tasks from the outside world.

3. Consideration of user resources
When designing a product, the designer should take the user's resources into account.

4. Feedback
The user interface should signal to the user when actions have been acknowledged and thereafter indicate the result of it in a meaningful way.

5. Error prevention and recovery
The product should be designed in a way that the risk of errors are minimized. If an error were to happen the user should be made aware of it and the procedures of fixing it should be quick and easy.

6. User control
The design should maximize the user control of the actions taken by the product and the status of it.

7. Visual clarity
The information presented in the user interface should be as clear and easy to interpret as possible without causing confusion.

8. Prioritization of functionality and information
The most important functionalities and information should be the easiest to access and interact with for the user.

9. Appropriate transfer of technology
The designer should make appropriate use of technologies from other contexts to increase the usability of the product.

10. Explicitness
The design should include clues on what the product can do and how it should be operated by the user.

2.3.2 Podmajersky's editing process for UX writing

The principles of usable design highlights the communicative aspects of user interfaces. Text is a major contributor to creating understanding and communicating information and meaning to the user. The semantics therefore becomes an important consideration for the usability of an interface that urges special attention. Podmajersky (2019) lays out an editing process consisting of four phases that can be used to improve user interfaces by assuring that text effectively fulfills its dedicated purposes. The four steps are the following:

1. Purposeful
The first step is to make the UX purposeful, both for the user and the organization providing the product or service. Find out what needs to be known about the user and the organization in order to make the UX text purposeful and useful. State the purpose(s) and make sure the interface fulfills them.

2. Concise
The second step is to reduce the amount of text in the interface. This is so that the user doesn't have to read unnecessary information and because the space in the interface is often limited. Therefore, the aim of this step is to shorten down the text presented to the user while keeping the core meaning of it.

3. Conversational
The third step is to make it conversational. By making the text less abrupt and more in a human conversational tone it will become recognizable for the person interacting with the interface. The purpose is to make it so that the user has a conversation with the text.

4. Clear
The fourth and last step is to check that the message is clear. Going back to the stated purpose(s) from the first step, it should be ensured that what is to be communicated is clearly expressed. The UX text should contain common words and words that the users will recognize.

2.3.3 Semantic interaction design

Graphic design also performs a communicative role and impacts the understanding of a user interface. In this case the semantics concerns meaning read out, not from words and sentences, but from the relationships and structure of content and graphic material. Consideration to these issues is essential for how a user understands the interface navigation and the function of different types of content on screen. Within interaction design a semantic grid defines the placement of on screen content, specifically the placement of different types of selectable content (Rosenberg, 2020). The grid is essential for comprehension of and differentiation between global and local interactions, i.e. those who change or control events for the whole interface versus those who act on one area or one page of the interface. Users expect global interactions to be resided in headers and local interactions in the page body together with content they have an effect on or control. Rosenberg (2020) argues that content structure should follow a consistent mapping throughout the interface, i.e the placement of a specific type of interactive feature should always be in the same space and visualized in the same fashion. This is specifically applicable for multiple level page navigation, where there are main tabs which itself contain tabs for more detailed page selection. In this case the different levels can be differentiated through grid placement, visual appearance and control style.

2.4 Technology adoption and acceptance

Development of completely novel solutions or redesigns of existing features requires consideration to how users are going to adapt to and accept the solution. In the construction industry where the current culture results in a resistance to change (Oesterreich & Teuteberg, 2016), this is a particularly important consideration. To ascertain that the development work results in designs that are accepted and implemented by both new and existing users, theory relating to the technology acceptance model, product feature upgrades and scaffolding has been considered and will be presented in this section.

2.4.1 Technology acceptance model

Since achieving high levels of user acceptance is a central part of the design work, it is important to first create a foundation for understanding the factors and mechanisms that determine how users adopt new technology. The Technology Acceptance Model is a synthesis of a number of preceding theories from various disciplines regarding adoption and acceptance of innovations and technology (Davis, 1989). It presents perceived usefulness (PU) and perceived ease of use (PEOU) as fundamental tenets for acceptance and usage of technology. Davis (1989) also develops a framework for evaluation of these two tenets as a basis for understanding user acceptance. In this framework perceived usefulness is connected to performance aspects such as productivity and effectiveness while perceived ease of use is connected to learnability, clarity, flexibility and the ease of becoming skillful.

Davis (1989) argues that PU and PEOU are not exclusive in determining actual use of a technology but that they showcase strong correlation and can be used as a fundamental measurement. PU shows the strongest correlation with actual usage indicating that ease of use can not be used as a supplement in pursuing users to accept technology. A product that is perceived as useful can be accepted even if it is not perceived as easy to use but a product that is perceived as easy to use but not useful will with most certainty not be accepted (Davis, 1989).

Park and Park (2020) extends and adapts the technology acceptance model for the construction industry. They argue it is different from other industries in the way that information technology is often introduced, not through a perceived need from the users but rather external factors and stakeholders that prescribe use. Park and Park (2020) put forward four factors that moderate PU and PEOU:

Acceptance type
Moderates PU. Users with general fast acceptance of technology perceive construction IT as more useful.

Educational satisfaction
Moderates PU and PEOU. Users that have experienced satisfactory education in the construction IT perceives it as more useful and easy to use.

Usage enjoyment
Moderates PU. Users that experience the interaction with construction IT as pleasurable perceives it as more useful.

Usage experience
Moderates PU and PEOU. Users that have previous experience with construction IT perceive it as more useful and easy to use.

Park and Park (2020) put special emphasis on education, which they argue is essential in achieving technology acceptance. They say that enough education and guidance in a new technology is necessary for new users to accept the technology and that extensive updates of existing technology urges extensive guidance for users in order not to lose them.

2.4.2 Acceptance of product feature upgrades

Strawderman and Huang (2012) elaborates on the user acceptance in relation to product upgrades. They argue it is essential to consider user acceptance towards novel solutions not only in the case of entirely new features but also when existing features undergo upgrades. They distinguish between two types of usage tasks and three types of product upgrades. Automated tasks are performed by users with little knowledge processing and analysis due to them being performed using similar information often and thus becoming learned. Controlled tasks require different actions depending on the use scenario and thus can not be automated. In the case of upgrade type a product can undergo omission (removal of a step), commission (addition of a step) and sequence (change of step order).

Strawderman and Huang (2012) argues that all three types of design changes lead to short term drops in user performance (increased time to complete a task). However, users recover better from these design changes in controlled tasks where no previous behavior has been learnt. For automated tasks on the other hand, product changes can have lasting detrimental effects and thus has to be carefully evaluated before implementation. Especially commission and omission has more far reaching performance implications. A change of sequence to automated tasks is thus preferable over adding or removing steps (Strawderman & Huang, 2012)

2.4.3 Scaffolding

Since education within both novel and updated technological solutions is highlighted as particularly important for user acceptance, it is relevant to consider a structure for learning and how its implementation impacts the learning experience. This is particularly relevant as Brinja currently relies on in person introductions of their technology, a solution which is not fully scalable for future offerings. Scaffolding is a temporary learning support that is adapted to a learner's explorative learning experience (Janson et al., 2020). The concept is applicable both in traditional teaching and in technology assisted learning procedures. In non-technology assisted procedures these structures are provided by people such as teachers or instructors, who provide scaffolding in the form of temporary guidance to learn new tasks.

Technology-enhanced scaffolding fulfills the same purpose but the teacher is replaced by IT. The purpose of such a structure is to aid learners getting a grip of the overwhelming amount of options and ill-structure present at first contact with a new procedure. Janson et al. (2020) show that technology-enhanced scaffolding can improve learning satisfaction and limit the cognitive load associated with acquiring knowledge of new tasks and procedures. It does so by limiting the extraneous cognitive load, i.e. the cognitive load associated with processing the information of the learning activity itself or the instructional complexity and design.

3. Methodology

During this thesis work, a spectrum of methodology has been used both to acquire and analyze insights from the current state of operation and for the design of novel solutions. This chapter presents the methods used and their purposes. The methods are categorized into the areas of theoretical evaluations, empirical research, synthesis of insights, and concept generation.

3.1 Theoretic research

To generate an early understanding of the app and its use, prior to acquisition of interviewees, a number of theoretic evaluation methods have been utilized. Theoretic evaluation consists of analysis of principles and concepts without practical application. It can act to acquire insights into potential theoretical use cases without involving the actual users. The theoretical evaluation methods used for this project are literature review, hierarchical task analysis, enhanced cognitive walkthrough, predictive use error analysis, heuristic evaluation, and Plus-Minus-Interesting.

3.1.1 Literature review

Acquiring insights within areas where no previous design exists, requires methodology which is not dependent on evaluations of existing solutions. In these cases, standards and previous research and observations from similar areas can be used. A literature review is a method which aims to uncover knowledge and deepen understanding of a topic. Performing one provides an understanding of the current research within the topic, identifying what is known and unknown. A literature review can consist of a summary and analysis of the gathered research and theories (The University of Edinburgh, 2021).

3.1.2 Hierarchical task analysis

The design of usable solutions requires deep understanding of the tasks a user performs, how they are performed and for what purposes. This information is also relevant as a framework for a number of theoretic evaluation methods, and establishing user task performance is thus an appropriate first undertaking. Hierarchical task analysis (HTA) is a method that provides a structured way of listing the tasks that a user needs to perform to achieve a certain result. When performing an HTA, one must have a detailed understanding of the task. This requires identifying the user goal and then detailing each step the user needs to take in order to accomplish this goal. These are thereafter structured in a tree diagram. (Stanton, 2006)

3.1.3 Enhanced cognitive walkthrough & Predictive use error analysis

As the tasks of a user have been established and the steps taken to perform them are known, further analysis of how the user interface supports task completion can be undertaken. An important first step is to ascertain that no vital use errors will result from the design of the user interface. An Enhanced cognitive walkthrough (ECW) is a methodological simulation of a user's steps of interacting with an interface where the tasks of an HTA lays as a foundation of the investigation. The walkthrough covers investigation concerning whether the user will accomplish the correct action. A list of questions is reviewed in order to identify potential problems of use. These problems are then graded by problem seriousness and then categorized into what type of usability problem that can occur. Predictive use error analysis (PUEA) consists of predicting and identifying potential use errors in each of the steps the user interaction consists of. The errors are investigated through a set of questions with the perspective of the simulated user. The questions are categorized into: type of error, consequences, and mitigations of the error and consequences. These two methods ECW & PUEA can be combined for a thorough method of identifying and analyzing errors. (Bligård & Osvalder, 2007)

3.1.4 Heuristic evaluation

Identification of error prone behaviors is important for understanding how to improve a user interface but it mostly covers the minimum viable requirements for the design. To get a more nuanced holistic understanding of both positive and negative features and design elements concerning usability, another method is suitable as a complement. Nielsen (1994) presents a heuristic evaluation (HE) which is a set of principles for interaction design which cover 10 heuristics that when applied to a user interface can act as an evaluation method. The purpose of the method is to find ways of improving user interfaces and the user interaction, but it can also highlight what aspects work well and should be kept or developed further. The 10 heuristics are the following:

Visibility of system status
The design should clearly display the status of the system to keep users informed. Present feedback as fast as possible and maintain a continuous communication with the user.

Match between system and the real world
The design should follow conventions that are used in the real world. Terminology, concepts and symbols that are well known by the designer might be unfamiliar to the user. Using conventions from the real world will therefore make the design more intuitive and better understood.

User control and freedom
Since users sometimes make mistakes, there should always be an option to leave with changes unsaved. Exit and undo buttons gives the users a sense of control and freedom.

Consistency and standards
Users spend more time with other products and services. It is these experiences that set their expectations of how the design should function. The design should therefore follow platform and industry standards to make the interface more intuitive and increase learnability.

Error prevention
Prevent the user from performing errors. Prioritize the situations when the users make the most errors and utilize constraints and confirmation options when users make crutial decisions.

Recognition rather than recall
Design so that users have to remember as little information as possible. Display elements, options and actions to the user in order to make them recognize rather than recall information. Since users have a limited short-term memory, recognition rather than recall decreases the cognitive burden of the user.

Flexibility and efficiency of use
Design functions so that tasks can be performed in multiple ways in order to improve the usability for both novice and expert users. Add shortcuts and allow user personalization and customization to increase flexibility and consequently efficiency of use.

Aesthetic and minimalist design
Remove unnecessary content and visual elements to maintain a minimalist design and decrease the risk of distracting the user. Focus on the essential aspects of the design and make sure it enables the user to accomplish their primary goals.

Help users recognize, diagnose, and recover from errors
Design so that error messages become easy to understand, indicate the problem and suggest a solution in plain language.

Help and documentation
Sometimes the user needs an explanation of how to perform certain tasks. Help documentation that is clear and concise can then be provided to support the users with their tasks.

3.1.5 Plus-Minus-Interesting

While the thorough evaluation methods highlighted above are effective tools for uncovering insights about usability in all areas of the design, they are relatively time consuming. When requiring formative evaluation of developed concepts they can be restrictive in terms of substantially interfering with the creative process. For this purpose a fast method which allows all aspects of the design to be discussed is preferable. Plus-Minus-Interesting (PMI) is a method of critically thinking about and listing positive, negative and interesting aspects of a solution, product, or service. The PMI helps identify and reflect on strengths and weaknesses of what's in focus. Furthermore, it supports an open dialogue and making decisions (Roy, 2021).

3.2 Empirical research

For actual confirmation of the insights gathered from theoretical research methods and to generate insights from the actual context of use, empirical evidence is necessary. Empirical research collects insights from actual experience rather than from theory. It thus covers experiential aspects of interaction and anchors the findings in the needs and concerns of actual users and their environment. In this project, empirical data has been collected through interviews.

3.2.1 Interview

Interviews are suitable for this purpose as they allow users to contribute with perspectives from their specific usage and expertise, even from previous situations through recollection. An interview is a conversational research method with the purpose of uncovering the views, attitudes, behaviors and needs of users. It can also be applied to gather expert knowledge from individuals with a particular skill or experience in an area. The method can be used as a means of creating a knowledge foundation for later design work or as an evaluative method for collecting feedback on developed designs (Wikberg Nilsson et al., 2015). Interviews take the form of a discussion between an interviewer and interviewee(s) and can be structured in various ways (Brinkman, 2014). Unstructured interviews are open-ended without predefined questions but rather a general direction of inquiry which the interviewee is free to explore as they wish. Semi structured interviews have predefined questions which allow the interviewer to steer the conversation to areas of relevance for the project while still allowing the interviewee freedom to elaborate on areas of importance to them. Interviews can be performed either in groups or individually.

Group interviews are beneficial for exploration of fields when previous knowledge is scarce, as they can provide a nuanced discussion where individual differences in views appear (Brinkman, 2014).

3.3 Synthesis of insights

Theoretical and empirical research results in large amounts of unstructured collected data. Methodology for synthesizing insights can be used to narrow down the broad data from research to more manageable information. In this section the methods used for synthesizing the collected data are described beginning with the KJ method followed by design specification.

3.3.1 KJ method

An initial step in the synthesis is to structure the data into more manageable chunks which can be used to form hypotheses in separate areas as a basis for future work. The KJ method, also known as affinity diagramming, is a technique for organizing qualitative data gathered from for example interviews. The set of data is sorted into labeled groups of similarity where the data in each group have a common theme that ties them together. The purpose of the method is to support the formulation of a hypothesis around the subject that the data is set around (Kawakita, 1982).

3.3.2 Design specification

Once the research area is starting to crystallize, insights regarding how a solution should be designed is uncovered. However, to efficiently support design work and to act as a foundation for evaluation of designs, the insights need to assume a stricter form in order to be easily revisited during the full process. A design specification can serve this purpose. A design specification is a document that collects what the designed product needs to satisfy in relation to standards and identified needs. The specification consists of a list of requirements and guidelines. The list is assembled to help the designers align their view of what is to be designed and support evaluation by providing a reference of what the design should entail. The design specification is a dynamic document that changes as new information and priorities are uncovered, and thus becomes more accurate during the course of the project (Wikberg Nilsson et al., 2015).

3.4 Concept development

Once a foundation of insights regarding how a solution should be designed has been established, development of concepts can commence. Concept development makes use of the synthesized insights from research but requires methods for actually generating new concepts and then developing them to functional solutions. In this project, the methodology used for this purpose is braindrawing and digital prototyping.

3.4.1 Braindrawing

During early phases of product development a central focus of the work is to generate new solutions. For this purpose it is beneficial to have a limited focus on issues and viability of designs, as this can limit the development of solutions that can later turn out to be successful. Braindrawing is a method that utilizes sketching to generate a large amount of ideas. The method is to stimulate new perspectives and crazy ideas, as sketching takes place with no critiquing during the session. The designers work to generate a quantity of ideas. The quality is secondary as it can be improved in later stages. Combination of ideas, to generate full solutions from successful sub solutions, is an important part of braindrawing (Wikberg Nilsson et al., 2015).

3.4.2 Digital prototyping

During later stages of development, the viability, functionality, interaction and aesthetics of the design becomes more important. Accurately incorporating these aspects in the design is therefore important, something which can be achieved through digital prototyping. Prototyping is a technique commonly used within human-computer interaction. It is often seen as a means to evaluate and test designs but it is also an essential part of concept generation and ideation where it can act to conceptualize abstract internal representations and communicate with others (Lim et al., 2008).

Digital interface prototypes can be of varying scope depending on what is of interest to encompass. A full prototype covers the entire interface while horizontal prototypes cover the full breadth of the interface but only on a surface level. Vertical prototypes cover only select parts of the interface but in full depth with all functionality (Benyon et al., 2010). This division of focus can also be compared with the concept of filtering. Lim et al. (2008) argues that prototypes can be seen as filters, where the purpose of a prototype is to filter out and only embody the aspects that are of interest to the designer for the specific goal they are aiming to achieve with it. Depending on what the purpose of creating the prototype is, different aspects could be relevant to filter out. In relation to this, the designer needs to consider that the selection of filtering has an impact on how functional the prototype is in achieving its purpose. For example, a prototype that embodies properties that makes it feel finished even down to the realism of graphics but filters out the real names of customers could lead to users getting stuck on the one thing which does not behave as expected, limiting the evaluative success of other aspects.

Benyon et al. (2010) argues that the best evaluative results are achieved if the user interacts with the prototype on their own without intervention. However, a lack of context can make the interaction with the prototype difficult to relate to, why delivery of the prototype to the user is beneficially accompanied with a scenario or with the instruction to complete an existing task if the design is replacing a previous solution (Benyon et al., 2010).

4. Process

This chapter introduces the process and the application of methodology used in this thesis work. First an overview of the overall structure of the process is presented. Thereafter follows a detailed description and motivation of the seven major phases of the thesis work, where the application of methodology used is highlighted.

4.1 Overview

The whole design process of the thesis work is visualized in figure 4.1. Initially the thesis work covered a thorough discovery phase. The purpose was to gather information and to get an understanding of user needs and wants, to see what industry standards look like, and to evaluate the current design of the app for the focus areas that were to be examined. This broadening discovery phase served to acquire a holistic view of the context, the app, the users and their goals. Thereafter, the thesis work narrowed down through funneling of the acquired insights into requirements and guidelines that were to be considered during the development phase. This definition phase served to analyze the breadth of views and insights collected and translate them into a manageable framework in the form of a design specification.

During the development phase, the thesis work diverged again as ideation began and a multitude of solutions were developed. The purpose of this phase was to explore the design space and the possible solutions for each of the focus areas. When concepts had been generated, the evaluation phase began. In this phase the concepts were shown to users with the purpose of receiving feedback, based on which the design specification was updated.

The next phase consisted of refinement. In a second major iteration, the wireframes were revisited with the aim of improving them based on the acquired feedback. When the concepts had been improved, the verification phase began. This verification consisted of summative evaluation in the form of matching against requirements and evaluation to confirm improvements. Lastly, the concepts were finalized and prepared for delivery to developers at Brinja.

Conclusively, the processes can be divided into two iterations after the initial phases of discovery and definition. Within these two iterations smaller and more intensive iterations have been performed with the aim of allowing for constant incremental improvements and refinements. The purpose of having two major iterations for concept development has been to enable the collection of empirical data in relation to developed concepts and to aid users in voicing their needs and concerns. The thesis work has been research oriented with the users in the center. This has served to lay a foundation of insights regarding the user's needs which then could be used during the development and refinement phases.

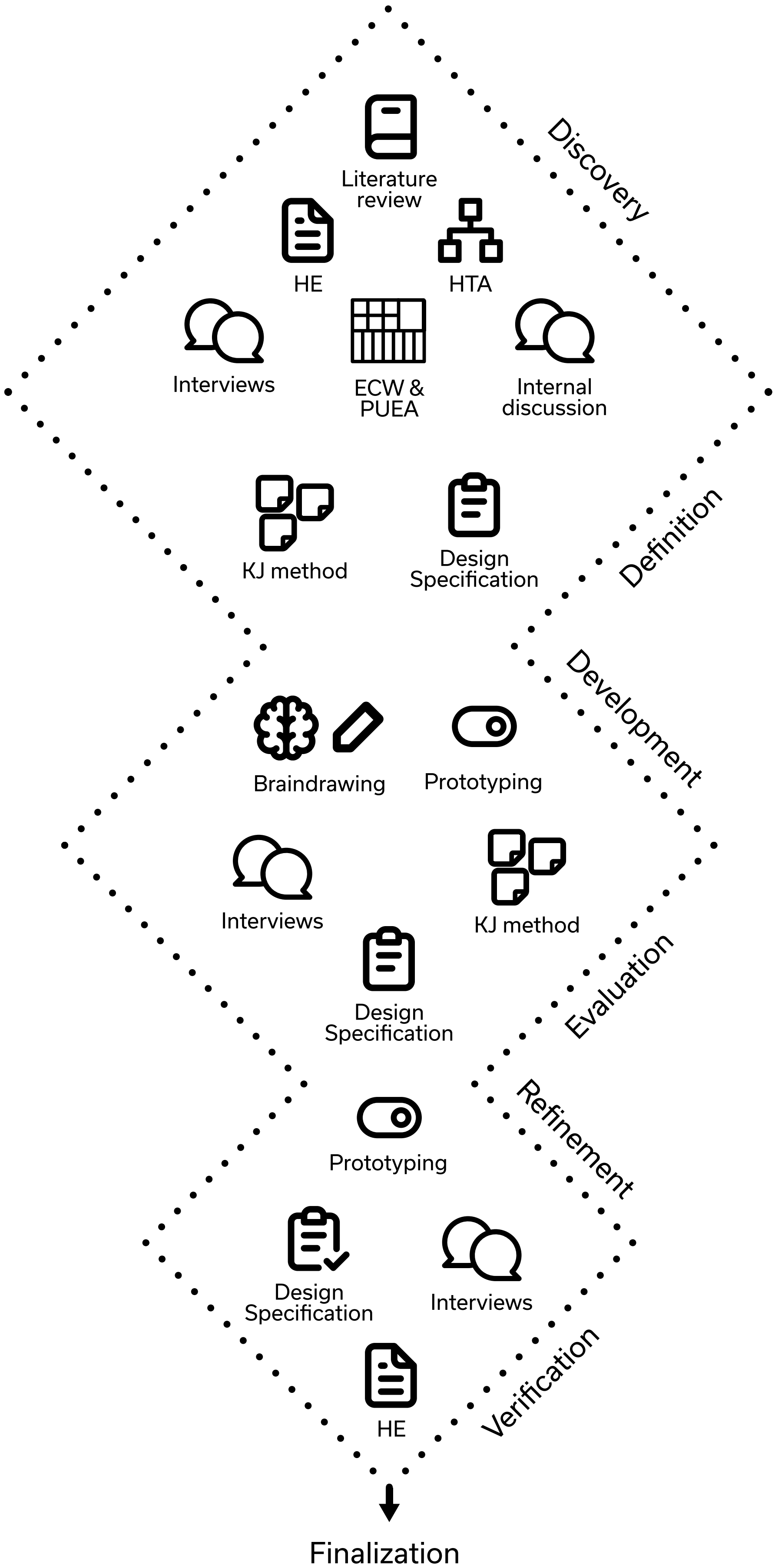

Figure 4.1. *Overview of the process.*

4.2 Discovery phase

The process was initiated with a discovery phase with the aim of uncovering user needs, investigating how work is currently performed in relation to the Brinja app and how the current version of the app performed from a usability perspective. This section presents the application of methods for this purpose.

4.2.1 Literature review

During this project, literature reviews have been performed within two fields. Firstly, within the domain of design theory and methodology as a means for establishing a knowledge framework for the entire project. Secondly, with the focus of standards used for location description and naming within the construction industry as a reference for the focus area of location description.

Design theory and methodology
Literature regarding design theory and methodology was gathered for application during the project. Theory and methods were sought in the fields of usability, cognitive ergonomics, technology adoption and acceptance, theoretical evaluations, empirical research, synthesis of insights, and concept generation. This research served as a foundation for the whole process, from research to the refinement of concept, and was used when developing all design suggestions. The utilized theory and methodology found is presented in chapter 2 and 3.

Location description standards
To create an understanding of standards for naming of locations at construction sites a literature review was conducted. The literature review aimed at acquiring theoretic reference material for ideation and concept development and consisted of examination of official documents within the field of construction from the Swedish Institute for Standards and the International Organization for Standardization. These sources were chosen for their widespread recognition and history of leading the adoption of standards. The results of the literature review can be seen in section 5.1.

4.2.2 Internal discussions

An important part of the discovery phase was to establish the effects that a redesign should serve to achieve. For this purpose, to anchor the project in the needs of Brinja as a company and their history and experience from the industry, internal discussions were an important source of insights. Internal discussions to ascertain direction and receive feedback in relation to corporate insights were then continuously utilized throughout the project.

4.2.3 Hierarchical task analysis

HTA:s where performed to get an overview of the existing focus areas' structures in terms of the tasks and subtasks that the users need to perform to accomplish their goals. The focus areas for which HTA:s where performed were data visualization, setting up new projects, and setting up new devices. The HTA of setting up new devices was thereafter used when performing the ECW & PUEA. The HTA:s can be found in appendix A.

4.2.4 Enhanced cognitive walkthrough & predictive use error analysis

For the focus area of setting up a new device, an enhanced cognitive walkthrough & predictive use error analysis was performed. The method was applied specifically on an existing concept that had not yet been implemented by Brinja. This focus area was deemed to be the most complicated of the existing focus areas and the one where errors were relatively likely to happen. Therefore it was chosen for this analysis. The purpose of the analysis was to identify parts where the user could make errors and thereafter apply the learnings to the solution that was to be designed. The enhanced cognitive walkthrough & predictive use error analysis can be found in appendix B. The results of the method were synthesized to requirements and guidelines which can be seen, with references to the method as source, in appendix F.

4.2.5 Heuristic evaluation

Heuristic evaluations were performed on the focus areas that already exist within the app. These areas were data visualization, setting up new projects, and setting up new devices. The purpose was to gain a thorough understanding of the strenghts and weaknesses of the usability of these areas. Insights which could then be used to improve the usability of what was to be designed. The heuristic evaluations can be found in appendix C. The results of the heuristic evaluation were synthesized to requirements and guidelines which can be seen, with references to the heuristic evaluation as source, in appendix F.

4.2.6 Interview

For the discovery phase six people were interviewed in semi-structured interviews. Three of them were supervisors at a construction site, two were site managers, and one was a Brinja employee. Their experiences of the Brinja app and what tasks they perform with it are presented in table 4.1. Interviewees 1 and 2 worked at the same site and were interviewed in one session, while interviewees 3 and 4 worked at another site and were interviewed in one session as well. Group interviews were performed since they allowed for discussions which helped to gain more information from less experienced users since they complemented each other’s knowledge, and because different points of views could be discussed. The two group interviews were recorded and transcribed. For the interview with the Brinja employee, notes were taken. The interview questions that were used when interviewing the supervisors and site manager in the groups can be found in appendix D and cover all the focus areas of the project. The questions asked to the Brinja employee covered only questions regarding the installation of new devices and can be found in appendix E. The aim of the interviews was to get an understanding of the user needs and requirements related to the different focus areas. The results of the interviews can be seen in the first section of chapter 5 through 9 and in the design specification in appendix F.

Table 4.1. *Interviewees of the discovery phase.*

Interviewee	Role	Experience of the existing Brinja app	Tasks performed with the existing app
P1	Supervisor	Moderate	Data overview for spotting anomalies
P2	Supervisor	None	-
P3	Supervisor	High	Data visualization of concrete hardening process
P4	Site manager	High	Data overview of concrete hardening process
P5	Brinja employee	Expert	Installation of new devices
P6	Site manager	High (old version of app)	Evacuation, quality control through data visualization

4.3 Definition phase

The definition phase aimed to analyze and synthesize the data collected during discovery into a tangible design specification that could serve as a framework for development. This section highlights this process and the applied methodology.

4.3.1 KJ method

In order to organize the gathered qualitative data from the research phase the KJ method was used. From each of the performed and transcribed interviews useful data was extracted. This data concerned insights on how work is performed at the moment, what users lack and generally insights which could be used to formulate design specifications later on. The data was sorted into labeled groups whose content had similarities in theme. These themes could for example be "filtering" and "threshold visualization". The aim of this activity was to serve as help in formulating a design specification for each of the focus areas.

4.3.2 Design specification

A design specification of requirements and guidelines was created with the aim of defining what the users need and to be used as a guide when designing the solutions for the focus areas. As input for the design specifications, insights gathered from interviews, discussions with Brinja, Heuristic evaluations, the literature review, and ECW & PUEA was used. The design specification was iterated and developed as new information was gathered. The motivations for requirements and guidelines were supported by the theoretical framework. The final design specification can be seen in appendix F.

4.4 Development phase

The aim of the development phase was to translate the design specification to functioning solutions in the form of prototypes. Ideation to come up with a large amount of ideas functioned as a way to concretize viable solutions that fulfilled the identified requirements. This section describes this process and the reasoning behind methodological decisions.

4.4.1 Braindrawing

Braindrawing was used as an early method for generating ideas. It was applied for both ideation on the design of wireframes and on user flows and structure. Each focus area was ideated on separately but iteration between focus areas was applied in some instances where the design of one would impact others. This was to allow for a large focus on fulfilling relevant requirements for the functions separately while coordinating so that inconsistencies and clashes between different functions could be avoided. The ideation incorporated consideration of several theories in order to assure high usability from the start. The theories included the principles of usable design and Normans's theory on the psychology of artifacts for overall structure and Podmayersky's editing process for UX writing for design of feedback messages. PMI was used for formative evaluation during development of designs for the focus area of setting up new devices. It was applied by cross referencing the identified requirements and developed ideas to gain insights on which solutions were most viable and how combinations of solutions could result in successful prototypes. Based on these insights some solutions were discarded while others were selected for further work and improvement.

4.4.2 Digital prototyping

Digital prototyping was applied alongside and after braindrawing. The purpose of utilizing digital prototyping was to conceptualize ideas and thereby aid more detailed ideation on the solutions. Furthermore, it acted as a way to materialize the abstract personal ideas into a high enough fidelity that they could be understood and thereby mutually improved upon by both designers. This social aspect of materializing ideas was also utilized for communication with Brinja employees so that their expert competencies could be benefitted from. Lastly, once the design space had been thoroughly explored through iterative ideation and digital prototyping and one or a few solutions started to crystallize, the prototyping aimed at creating functional prototypes that could be used for evaluation.

The prototypes were developed in Figma as it allowed for an appropriate level of detail and interactivity in prototypes, while also being the current prototyping software used by Brinja. The prototypes that were developed for evaluation were vertical prototypes that covered only the select focus area and only one or two parallel flows within that focus area. For example, even if data prototypes displayed several house parts and floors only one or two of them were interactive so deeper levels could be accessed. However, in the interactive flow, the full depth of the interface was prototyped to allow evaluation of the full functionality of the design. This approach was selected as it was deemed more important to gain insights on all functionality rather than on the interaction and navigation between different parts of the interface.

The prototypes for evaluation were developed with close to finished design elements in order to give enough detail for evaluation even of lower element levels of the design. However, the finish in terms of color and graphics detail was different from the app.

A white sketch-like finish, as opposed to the dark blue design of the app, was actively chosen for the prototypes to make it clear to the users that it was a work in progress. This was considered important for two reasons. First, as not to be perceived as so finished that users would be afraid to critique it honestly. Secondly, that the visual level of finish would correspond to the level of finish of interactions. This is in line with how Lim et al. (2008) argues that filtering of high detail visuals can impact user expectations in a direction where everything is expected to function on the same level of finish as the graphics. By making graphics and interactivity correspond in their level of finish, users were expected to be less surprised by interactions that did not fully behave as a finished app, thus making them less inclined to spend time critiquing these aspects. This would allow for the aspects of interest, such as the structuring of information and method for displaying data, to be better covered in the evaluation. The concepts for evaluation can be seen in section 3 of chapter 5 through 9.

4.5 Evaluation phase

The evaluation phase, first and foremost aimed at testing developed prototypes with users in order to collect insights regarding how well the solutions supported the users and served their needs. For some of the focus areas this entailed gaining feedback on one developed prototype. For others it entailed feedback and comparison of two prototypes, in order to generate understanding of the benefits and drawbacks of the two, creating a basis for final concept selection and combination of prototypes. The evaluation phase also aimed to serve as a complementary needs identification to broaden the knowledge base collected during the discovery phase. The application of interviews as a means to generate these insights is explained in this section.

4.5.1 Interview

For evaluative data collection, semi-structured interviews were used. The selection of participants was made to cover users which together had experience of all the focus areas. For data visualization users with experience of both regular sensors and concrete sensors were selected, since this was found to influence the use scenarios and needs to a high degree. Furthermore users with varying levels of experience of the app were selected. This selection was made to account for the fact that experience level has an impact on the product's perceived usefulness and perceived ease of use, and thus influences how likely the user is to accept the solution (Park & Park, 2020). Furthermore, for the focus areas constituting an upgrade of an existing function, both users with previous experience of the feature and new users were selected. This was to ensure that the solution achieved good usability and user acceptance for both existing and new users. For location description the concept was evaluated as part of the concept for setting up a new device as this is the main point in the interface where location descriptions would be used. A summary of the interviewees for evaluation can be found in table 4.2. Some of these were interviewed during the discovery phase as well.

Table 4.2. *Intervewees of the evaluation phase.*

Interviewee	Role	Experience of the existing Brinja app	Tasks performed with the existing app	Prototype tested
P3	Supervisor	High	Data visualization of concrete hardening process	Data visualization with concrete
P4	Site manager	High	Data overview of concrete hardening process	Data visualization with concrete, add new project
P5	Brinja employee	Expert	Installation of new devices	Add new device
P7	Supervisor	Moderate	Data visualization and data export	Data visualization, add new device
P8	Supervisor	Moderate	Light control	Data visualization, add new device
P9	Supervisor	Moderate	Data visualization	Data visualization, add new device
P10	Site manager	Moderate	Data visualization	Messages, add new device
P11	Site manager	None	-	Messages

The interviews were structured to have the developed prototypes as mediating objects. It was decided that the user would be handed the prototype and be free to explore it individually with no previous explanation of the function. This was to make the results as representative as possible since it would be similar to real implementation in the future. Furthermore, this approach was to allow for additional data collection regarding user needs and expectations, as relatively free exploration would generate insights about which parts of the interface the user actively decides to access and thus give indications about what they consider important. This could guide further development of prioritization of content and filtering of information. However, to provide the user with context, the purpose of the new design was explained and they were asked to begin by trying to perform a task they would often perform in the existing app.

After the prototype had been handed to the user they were encouraged to continue to explore the app for a time and talk aloud about what they saw and thought while doing so. Questions from the users during their interaction were answered. In some instances where a user had not found a function in the prototype after a time of free exploration, it was shown to allow for feedback to be collected. Interview questions which had not been answered during the free exploration were asked afterwards. In the cases where two versions of concepts for a focus area were evaluated, comparing questions were also asked. The interview forms can be seen in appendix G and the results of the interviews can be seen in section 4 of chapter 5 through 9.

4.5.2 Design specification

As a part of the evaluation phase the design specification was updated with the insights and feedback gathered from the interviews and new requirements and guidelines were added. The purpose of this update was to help utilize the insights for the next phase of the project, when the concepts were to be refined. The final design specification can be seen in appendix F.

4.6 Refinement phase

The aim of the refinement phase was to first select final concepts to continue work on and secondly to refine these based on the insights collected during the evaluation. Concept selection was based on evaluation findings regarding usability and how the concepts supported users tasks. The concepts were developed and refined through further digital prototyping. This development work aimed to result in a finish of graphic style corresponding to how implementation in a finished app would look. This meant that the concepts were developed in the same dark blue style used in today's app and that detailed implementation of elements and illustrations on screen were refined. The resulting final design suggestions can be seen in section 5 of chapter 5 through 9.

4.7 Verification phase

The verification phase served to ascertain that the refinements had resulted in improvements in relation to research, evaluation findings and requirements and that no unanticipated adverse effects could be traced to the developments. Furthermore it acted as a final summative evaluation of the design suggestions in relation to the design specification.

4.7.1 Heuristic evaluation

Heuristic evaluations were performed on each concept. This was to examine that they were well designed from an interaction design perspective, and to uncover potential issues with the design. The heuristic evaluation can be found in appendix H.

4.7.2 Design specifications

To ensure that the concepts adhered to the design specifications that were set up for each of the focus areas of the thesis work, each design suggestion was verified against the corresponding requirements and guidelines.

4.7.3 Interview

Besides verifying the concepts towards the design specifications and performing heuristic evaluations, two interviews were conducted to get input on the data visualization. This focus area had multiple types of use cases and as a result the final design suggestion had a non-linear navigation that had not been incorporated in the initial evaluations. Furthermore, extensive changes to visualizations had been made to improve understanding. To gather insights about how this developed design would be received by users, additional empirical data was required. The two interviewees are listed in table 4.3 and the interview form can be seen in appendix G.

Table 4.3. *Intervewees of the verification phase*.

Interviewee	Role	Experience of the existing Brinja app	Tasks performed with the existing app
P3	Supervisor	High	Data visualization of concrete hardening process
P12	Site manager	High	Data visualization of concrete hardening process

4.8 Finalization phase

During the final phase of the process minor changes were made to the designs. The aim of this phase was to finalize the designs so that they could be handed over to developers at Brinja for implementation into the app. Together with the prototyped designs, notes were added to the files with instructions and clarifications of the design.

5. Results: Location description

This chapter presents the results from the focus area of location description in relation to the aim of investigating existing naming and suggesting a data model that supports understanding and task completion. It includes the findings from the conducted research, the design specification, a concept generated during the process, the evaluation results and the final design suggestion.

5.1 Research findings

Location descriptions on construction sites are already relatively widely developed as it is a necessity for several application areas for construction. The most obvious existing application is within drawings and CAD models where you need to locate objects and relate them to the real world. Furthermore, dedicated location descriptions are used by the construction workers when communicating and in other apps used for construction. Standards regarding location descriptions and naming of artifacts on construction sites already exist. The Swedish standard for naming on construction specifies that naming follows a hierarchical system increasing in detail for each level. The levels specified are house (hus), house part (husdel), floor (våning) and floor part (våningsdel) (Swedish Standards Institute, 2016). Two of these are used in the current Brinja app, house part and floor.

However, studies of other construction programs and apps, as well as interviews, indicated that the actual use of the standard in the industry is relatively low. Different programs use different systems although all are similar in its hierarchical structure. The main naming used on the sites differ between construction companies but also from project to project. This indicated that there is no definitive system which could be used and automatically match the system and mental models across construction sites. However, all interviews with current users of the Brinja app showed that the use of house part and floor is easily adapted to their varying internal systems. Although the exact naming is not always the same, the internal naming system can easily be incorporated into the categories of the app.

Except for the position description of house part and floor the current app also uses a label for naming of the individual devices. This is a free entry description. The interview with the expert user from Brinja highlighted issues with this system. Specifically, the label often becomes a duplicate of the house part and floor rather than a separate piece of information. In some instances it can also act as a more detailed specifier of location (with higher resolution than floor). While it is appreciated that a higher resolution than floor is supported, the separation of this information (into a label instead of together with other location data) makes the location description inconsistent. The naming system using a label also results in a division of information in the app based on devices. The empirical research indicated that this does not correspond to users' mental models and does not support optimal task performance. Users are interested in controlling lights and seeing data based on location, not based on device. While users can see where the device is located it would be more appropriate if the main division was on the basis of location.

Furthermore, since the existing system for location description is hidden from regular users it has never been adapted to be usable by someone without understanding of internal codes. The entry of house part in today's setup procedure is performed by writing a code that corresponds to a predefined type of house part (eg. staircase or chain house). Since today's users are familiar with these codes it is currently a functional approach. However, when construction workers will perform this themselves they can not be expected to learn this system. Furthermore, the use of these codes limit the freedom to generate namings which are always accurately mapped with the real world. If the construction site has an uncommon naming of certain house parts this is not supported by the predefined internal codes. The new system should therefore only require knowledge of the naming actually used on the construction site (not codes or abbreviations) and have the freedom to completely correspond to that naming.

5.2 Design specification

The research resulted in a design specification which can be seen in full in appendix F. Below is a summary of the most important requirements and guidelines.

The redesign should only require knowledge of the naming system used in the actual construction project. In relation to suiting each specific project, it was also considered important that the solution was scalable to accommodate various sizes of construction projects, e.g. that it can handle a high enough specificity even in very large projects with many devices.

5.3 Concept

Due to the issues highlighted above the location description concept incorporated a redesigned system where the label was removed and replaced with a location description as the primary identifier of devices. The current system for location description in the app was kept but an additional layer from the Swedish standard for naming on construction was added to allow for the higher resolution sometimes required. This resulted in three levels of detail; house part, floor and floor part. In the concept, all of these items were free entry for the user to be able to generate namings which completely correspond to their internal naming systems. Since three levels was not assumed to be necessary for all users the concept was designed to have optional entries.

5.4 Evaluation and feedback

Since the evaluation of the location description was part of the set up new device flow, insights regarding the location description were collected as a part of how users reacted to that. The first finding is that users had no issues understanding the different levels of the location description and the hierarchical order or entry from house part to floor part was intuitive for interviewees. Many users remarked on the new category of floor part, indicating that they recognised the previous two sections from the current app but reacted to the new addition. Some users stated that they did not need the floor part selection while others thought it was a good addition that could aid further specification of position. In the concept shown there was no clear indication that the floor part was optional, leading to some confusion regarding what to do with the entry when it was not necessary. This strengthened the assumption that specifically floor parts should be optional and showcased a need to highlight this in the interface design.

The structure of and information included in the location description was praised by users who thought it was simple to understand and corresponding to systems which they are used to. One user remarked that the system was similar to another app used in construction, namely EquipmentLoop. Another highlighted that the hierarchical structure reminded him of the map structure on PC:s which he related to and found relevant for this type of information. All users found it easy to connect the categories to what should be entered if they would use the system on their construction site and thought the names of categories were appropriate. One user said they used level (plan) instead of floor (våning) but that this was no issue. No users remarked on the removal of the label indicating that this removal would not result in a noticeable loss of any desirable information.

5.5 Design suggestion

The final design suggestion for location description contains three levels of information in a hierarchical structure which is illustrated in figure 5.1. The top level, house part (husdel), specifies the general location on the construction site. The second level, floor (våning), specifies the vertical location within a house part. The third level which is optional, floor part (våningsdel), specifies the detailed location within a floor. In writing the categories are separated by a slash icon. The location description also acts as the new system for device identification, i.e. a device now gets its in app identifier from its location. This means that there is no longer a distinction between a name for a device and the location where it is. This will eliminate the need for entering duplicate information and better correspond to users' mental models of location being the main information of interest when searching for or distinguishing between items in the app.

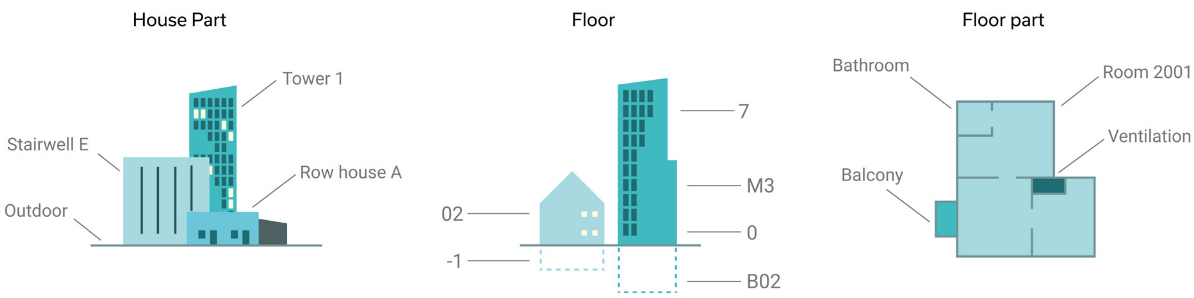

Figure 5.1. *Illustration of the design suggestion for location description.*

5.6 Summary

The most notable findings from the research includes that the Swedish standard for naming on construction specifies the use of a hierarchical naming scheme increasing in detail from house to floor part. However, the actual use of names from this standard within construction is low. Although the naming conventions vary, all studied construction sites make use of a hierarchical structure consisting of first a general specifier, then a vertical specifier and in some cases a detailed specifier. A location description that utilizes three levels from the standard, namely house part, floor and optionally floor part, therefore supports the entry of all identified types of information currently utilized for naming while satisfying the criteria of being scalable for different needs. Furthermore, evaluation showcased that this naming scheme mapped well with the mental models of users and that they therefore, despite varying internal naming systems, were able to effectively determine which information to enter when assigning locations. As a design proposal, the structure house part, floor and floor part is therefore suggested as a location description that serves to be the identifier of devices.

6. Results: Set up new device

This chapter presents the results of the focus area of setting up new devices in relation to the aim of establishing the user needs for independent completion of this task and the development of a design suggestion that effectively supports these needs. It includes the findings from the conducted research, the design specification, concept generated during the process, the evaluation results and the final design suggestion.

6.1 Research findings

Interviews with current users of the Brinja app showed that setting up devices themselves was not desired. Brinja coming to install devices is considered a service that is valuable to the customer and losing that service would be considered a drop in the value of the complete product offering. Reasons highlighted were time savings on their part but more prominently expertise and the need for the installation to be successful. Interviewees expressed how the Brinja employees that install devices know exactly what they are doing. The interviewees would not trust themselves to perform the installation accurately and appreciated being handed a ready to use system.

However, many interviewees also expressed that the current system of only allowing Brinja employees control over devices can be limiting in later stages of the project. Construction projects are highly dynamic and change over time. This also means that optimal placement of sensors changes over time. Many users expressed that they have wanted to move devices but then been faced with the dilemma of having to contact Brinja and ask them to come and reinstall only one device or move the device and have outdated location information attached to it. Users were therefore very positive about the possibility of them being able to reconfigure a device themselves. The function of setting up a new device is still necessary for the upcoming over the counter products. However, for customers like those currently in the Brinja ecosystem the set up of new devices is not a main focus. Instead movement of existing devices is important.

A significant consideration for the set up of new devices is that a large number of devices are often installed for each project. During the course of a construction project hundreds of devices could need installation, although such high numbers are not common. The current set up procedure, where Brinja comes to the site to install devices, also incorporates installation of many devices in one session. Brinja's expert user explained the setup as consisting of entering several devices into the app while in the same location, just collecting the devices for later placement on site. Once all devices have been entered the user would go to data and locate all the newly entered devices to assure that they function, after which the actual placement of the devices in different parts of the construction site would take place.

The movement of the installation responsibility to users on site (regarding the over the counter products) is likely to transform this activity to a more continuous one where not all devices are installed at once but ensuring good usability for set up of many devices is still important. Many findings regarding details for the set up procedure are also connected to this need to accommodate many repetitions of the set up activity, mainly stemming from the interview with Brinja's expert user.

One such finding is that the process should be as streamlined as possible. This entails including as few clicks as possible and collecting information entries on one page. The wish for one page entry is also rooted in the fact that this removes the need to navigate backwards to correct errors or make adjustments to entered information. Furthermore, user freedom to omit non-essential information entry (eg. adding a device to a group) was identified as important to further streamline the process. The need to go back to correct errors or to go through steps which were not considered necessary was expressed to result in frustration, which is likely to have a deteriorating effect on both perceived usefulness and ease of use and thus limit user acceptance. Another finding stemming from the current set up procedure is that the activity of ensuring proper functionality of devices is badly supported in the current flow. The expert user explained this activity as an obvious part of the set up procedure.

However, in the current app, since it is not supported in the same flow as the set up it becomes a separate activity which requires navigation through the data tab and its menu structure. The user did not highlight this as an issue but it was obvious that there was potential to increase the efficiency of the set up procedure by incorporating all necessary activities, including feedback on proper functionality, in one separate flow. This would also be specifically important for new users who would not have acquired the learnt process of ensuring proper functioning of newly installed devices in a separate part of the interface.

6.2 Design specification

The research resulted in a design specification which can be seen in full in appendix F. This section will summarize some of the most important requirements and guidelines.

First and foremost, a fundamental requirement, stemming from the new customer group that will have no contact with Brinja, was that users should be able to set up new devices in the app by themselves. This was complemented by a requirement to allow users to move or relabel existing devices in the app, stemming from the interview findings from existing users concerning placement changes.

Concerning ease of use, HE and ECW & PUEA resulted in a requirement stating that a novice user must understand what is to be scanned when adding a device to their project. The HE also resulted in a requirement that a user must be able to set up a new device in the app without external information. Furthermore, the number of unnecessary steps and visual elements should be minimized and the purpose of all information entries should be clear to the user in order to contribute to ease of use.

Necessary and purposeful information and steps, including those that limits the need to perform additional tasks after set up, should remain. The requirement of allowing users to add devices to threshold groups in the set up flow was included, since failure to do so would require users of the threshold group feature to make additional adjustments after having added a new device. Furthermore, requirements covering that users should get feedback, both concerning successful set up and in the form of a data reading, were included in order to incorporate the task of controlling proper functioning in the set up flow.

6.3 Concept

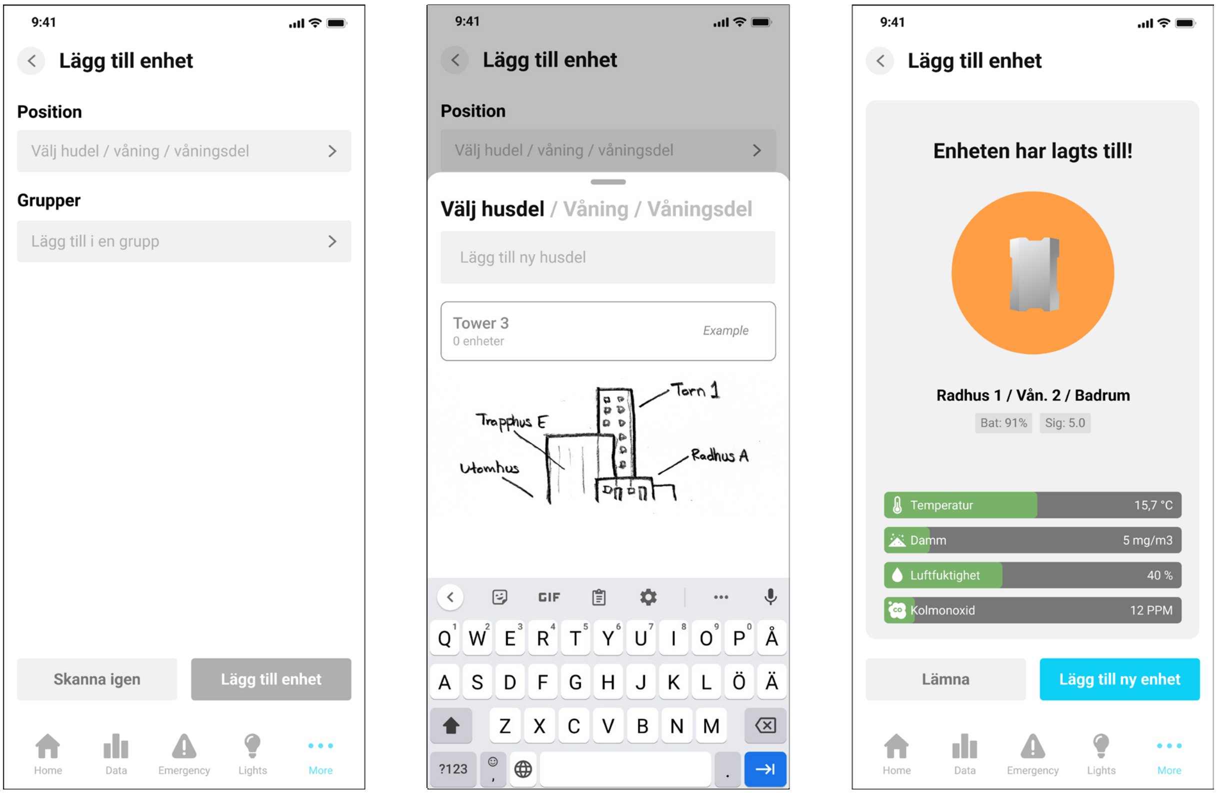

Figure 6.1. *Concept of set up new device.*

With the design specification as a framework, concepts were generated. Formative evaluation resulted in selection of one concept for user evaluation. This concept can be seen in figure 6.1. It first allows the user to define which device is being set up by entering the UID through scanning the QR code on the device or by entering it manually. After completion of this step the user is taken to the main page for information entry. Here, position and threshold group can be defined, both through a page overlay. The position entry contains three steps corresponding to the three levels of the new model for location description. The user first defines house part, then floor and lastly floor part. After having entered the desired information the user is taken to a feedback page that displays data from the device once it has been retrieved. The user can then continue to add a new device or leave the set-up.

6.4 Evaluation and feedback

The interviewees' opinions about the concept were positive. It was described as very simple and visually pleasing. The user flow was said to be smooth and as a whole it was considered easy to understand. One interviewee described it as following:

> – It's perfect. It's very clear. [...] I think it seems really good. Especially that you get the feedback right away. You don't even have to think about it, does it work? You get to test it right when you have added it. Perfect. [translated]

Interviewees also confirmed the findings from research that the ability to adjust the location of already existing devices would be of help.

– That's great because it has been tied to not moving anything because then you don't know where it is anymore, so it's great if you can do that. [translated]

One interviewee expressed appreciation for the mixed format of who installs and moves devices that is created through the redesign. He said that he would like Brinja to do the initial installation but that the ability for him to use the locations that Brinja have set up when moving a device would be good.

Two aspects of the design caused confusion in the tests with end users. First, an example box when adding a new device was interpreted as clickable by one user which it was not. Since the illustration below was designed to have the same explanatory purpose, the box was removed for later iterations. Secondly, interviewees did not interpret the addition of floor part as optional and thus were confused about what to do if they had no floor part to enter. In a later iteration the clickable text "skip" was added. In an evaluation of this modified concept the interviewee immediately interpreted the step as optional saying "and floor part, if you want", indicating that this modification clarified the functionality.

Brinja's expert user also identified areas that could be improved. The most notable request was that the UID and device type should be displayed on the information entry page as feedback for which device has been scanned. This is a request stemming from the workflow in which many devices are scanned right after each other without actual placement on site between. Here, the risk that the wrong device is scanned is heightened, increasing the need for feedback. The expert user also identified a need to be able to rescan the QR-code without having to redo the entering of location and group information in the case that you identify having scanned the wrong device after entering information. Going back one step to rescan was not considered an issue if the information stayed. These changes were accommodated in the final design suggestion.

Slight revisions to the feedback page were also suggested as a means to clarify that the feedback indicate that the set up procedure is complete and only waiting for optional confirmation input in the form of data readings. Except for this, the feedback page was appreciated for its graphic style and content which was referred to as fresh, professional and simple by interviewees. The feedback page that updates information dynamically in a graphical style can in this regard be understood from a perspective of not only fulfilling a purpose as information provision, but also immersing the user in more experiential aspects. The functionality is directly connected to a high perceived usefulness while the experiential aspects concern usage enjoyment which is also a determinant for perceived usefulness (Park and Park, 2020).

Keeping the location and group data from the previously added device in the cases where users add several devices in a row was also brought up as an improvement. The reason being that when users add several devices in a row the devices are likely to have very similar location data where only one level of the hierarchy needs to be changed. By keeping the data users do not need to fill out all the information again but instead change one part of the information. Furthermore the filled out data acts as memory guidance to which was the last location, meaning that the user does not have to remember from one device to another what has already been entered.

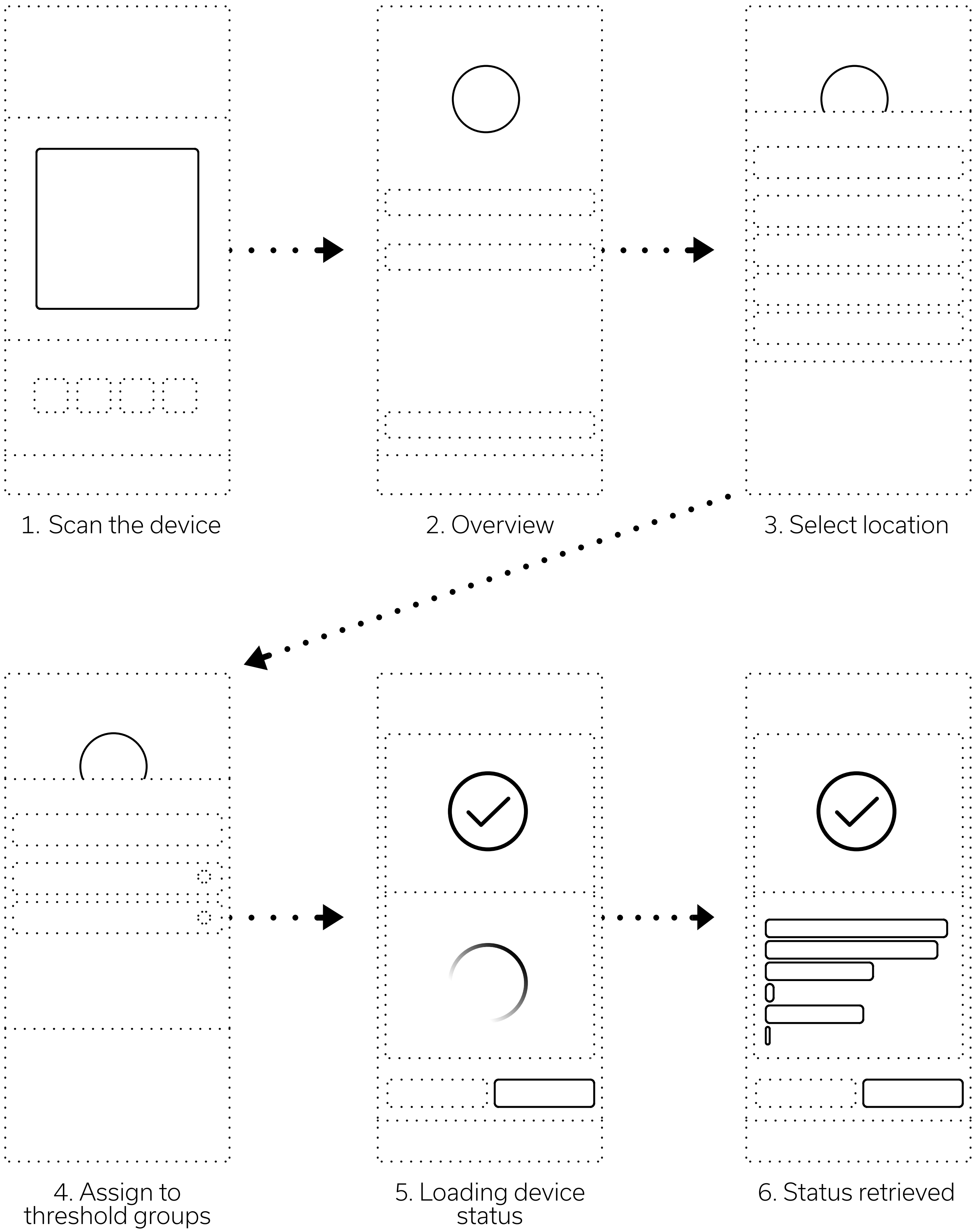

Figure 6.2. *User flow of set up new device.*

6.5 Design suggestion

The flow for setting up a new device is accessed either through the home tab shortcut plus button or through devices under more. The shortcut button creates fast access which is important for this relatively common task. The flow for setting up new devices is showcased in figure 6.2.

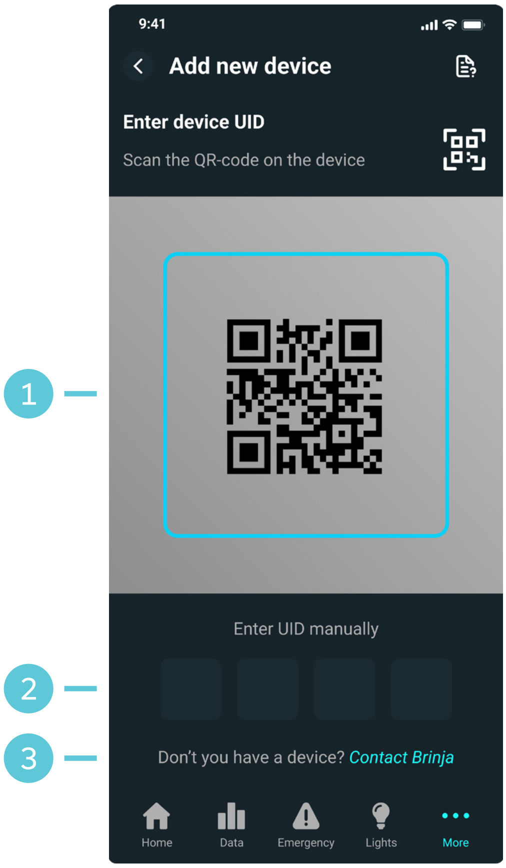

Figure 6.3. *Scan UID page*.

Once users enter the set up new device flow they are first met with a page for entering UID information. The most likely approach for this is through scanning the QR-code (1) on the device but the option of assigning UID manually (2) also remains as freedom to users but also as a measure if scanning fails or is impossible. The introduction of a new segment of customers with over the counter products requires the app to be opened up to users with no previous contact with Brinja. This means that customers who have not yet bought devices could reach the set up new device page. For this reason, guidance with the possibility of direct contact with Brinja (3) has been added at the bottom of the page. Once a QR-code has been scanned the user is taken to the information entry page (figure 6.4).

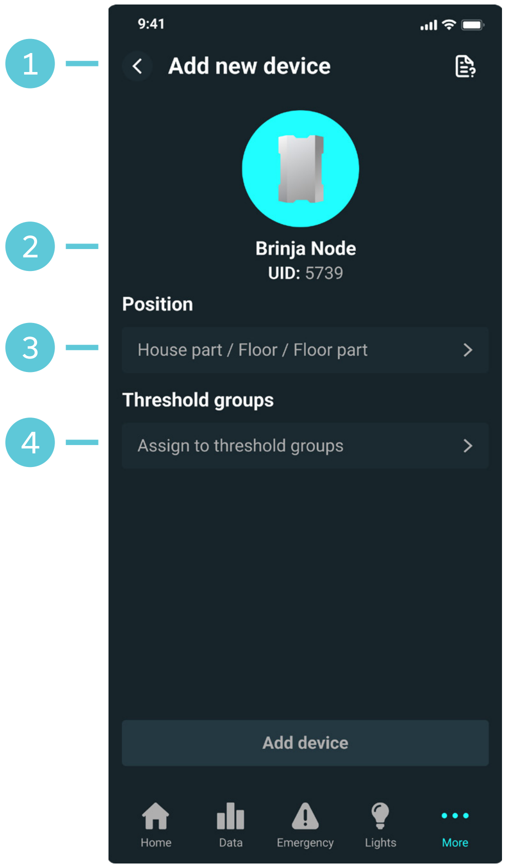

Figure 6.4. *Overview page 1*.

The information entry page first contains feedback of which device has been scanned (2). The device type is illustrated through image and text to act as confirmation that the correct device type has been scanned, mainly for inexperienced users. The page also contains entry fields for position (3) and threshold groups (4), which both open overlays for the information entry (see figure 6.6 and 6.10 respectively). Brinja's instruction manual for the installation can be accessed on the top of the page (1). This is available in the same place throughout the set up flow as the installation or placement on site can happen at any time during the set up procedure in the app. The format of the instruction access point is a tradeoff between experienced and inexperienced user usability. It was considered important to be able to access the instructions in the same flow as the set up in the app for an inexperienced user. However, once a user has installed a limited number of devices the installation becomes a learnt behavior which does not require the instructions. For this reason it was considered beneficial that the access point takes up a limited visual space on the page.

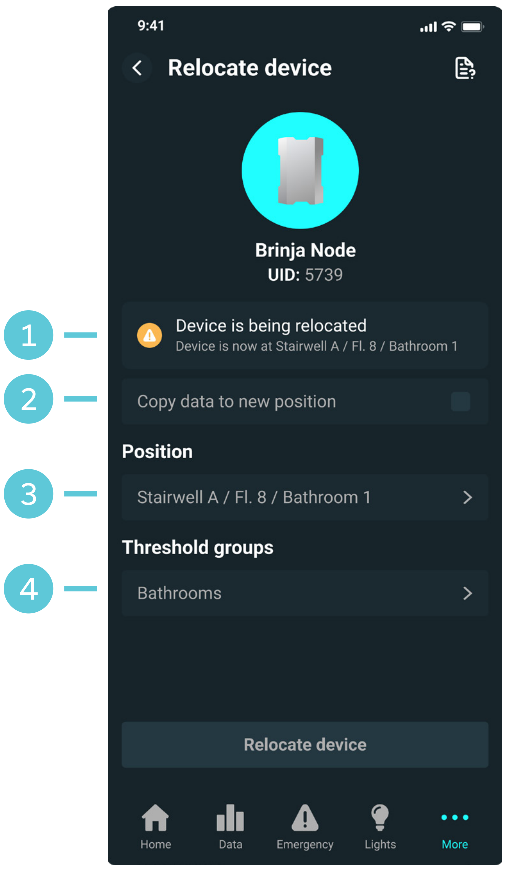

Figure 6.5. *Overview page 2*.

If a unit that has already been assigned a location is scanned the interface is slightly different than for a first time installation. First there is a feedback box (1) that clarifies that the device will be moved. This acts both as an error preventing measure in case the user was not intending to move a device and a clarification of the current assigned location of the device. There is also a check-box option (2) for copying the already collected data to the new location. The default is that data will only be shown on the previous location but in some instances a user could want the old data displayed on both the old and new location (eg. if the device was in an open space which has now been divided by inside walls). The position (3) and threshold groups (4) are also filled out with the information currently assigned to the device. This acts to support memory when reassigning but also to limit the amount of information that needs to be changed.

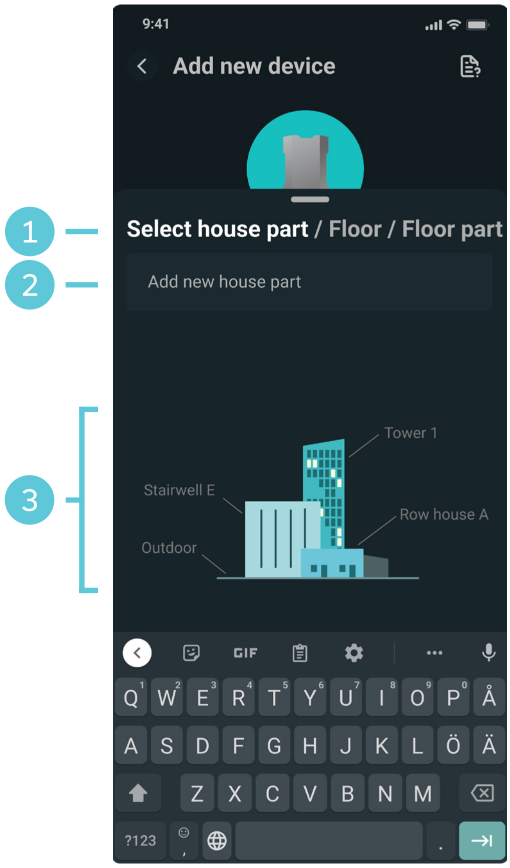

Figure 6.6. *Location overlay*.

For a user that has not yet installed any devices the overlay for position selection looks as in figure 6.6. It contains a combined progress and selection indicator (1). Here the relationship between the three levels of the location description are shown. As a user gradually defines a house part and floor the indicator becomes filled out with the entered information. For a new user this is especially helpful as it guides them through what to enter at the different steps. By seeing what the name of the following categories are the user gets insight into how specific they should be at each step. The example illustration (3) gives additional guidance on what can be entered. The text entry box (2) is where the user writes the name of the position, in the case of figure 6.7 the house part.

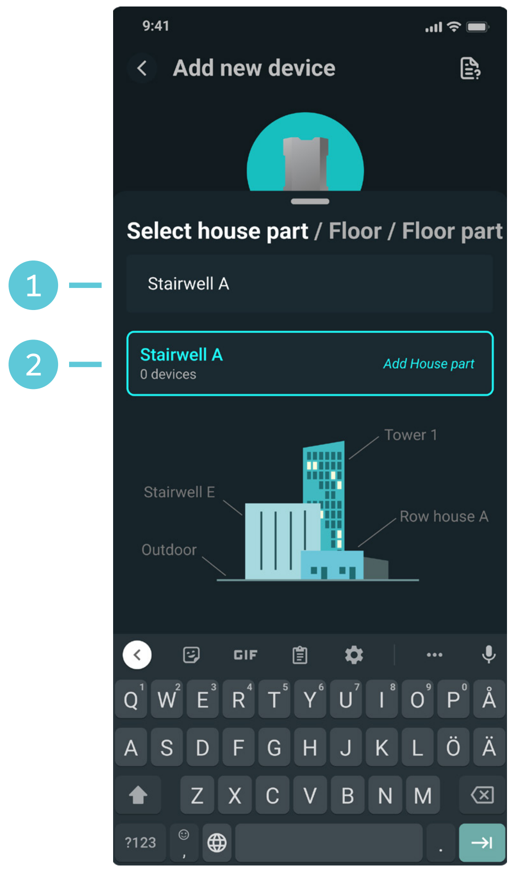

Figure 6.7. *Typed house part*.

As the user enters text in the text box (1), a new house part is generated (2). The text of the new house part mirrors that which the user has entered. By pressing the generated house part (2), the user adds it to the project and assigns the device to this house part. At the same time the overlay changes to the next level in the position assignment, in this case floor, where the same procedure is repeated.

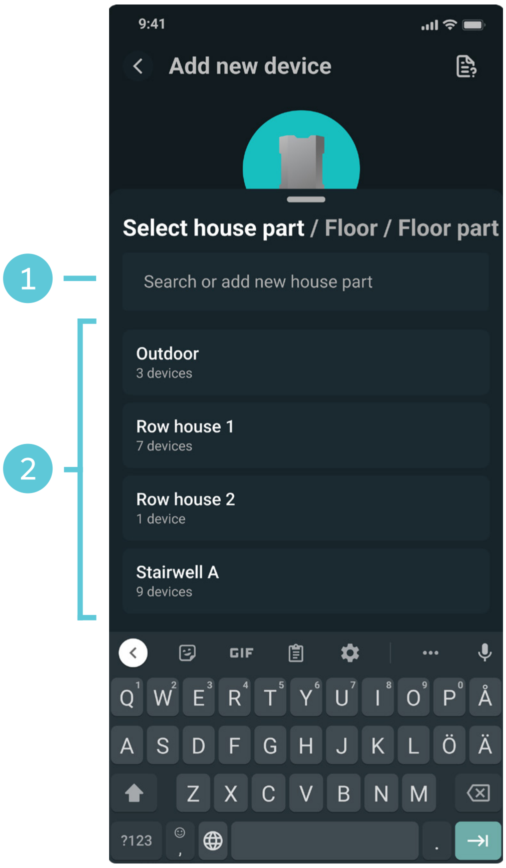

Figure 6.8. *House part*.

When positions have already been created through the procedure described above, the position assignment will include the already created positions as selections to choose from (2). When assigning position for the new device the user can now select from the list if the device is to be added to an already created position. The user can still generate a new position by writing in the text box (1), in which case an outlined box with the text “add house part” (see figure 6.7) will appear. The text box also functions as a search feature where already created positions that do not match the entered text are filtered away.

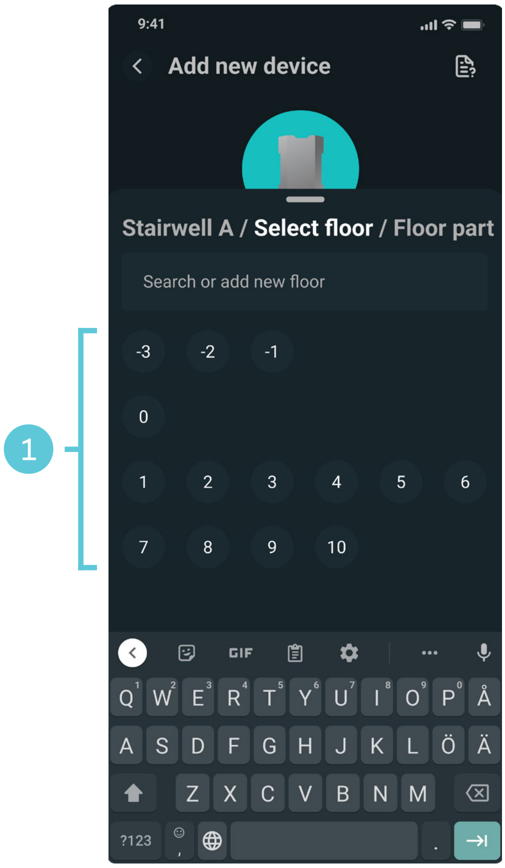

Figure 6.9. *Select floor*.

The selection of floor functions the same way as house part and floor part, but has a more compact design to accommodate the large numbers of floors that are possible. The field for showing and selecting already created floors (1) consists of several floors per row, but they can be selected in a similar fashion as house part by pressing a floor. To accommodate mapping with users’ mental model of order, the different items can be moved by holding and dragging an item.

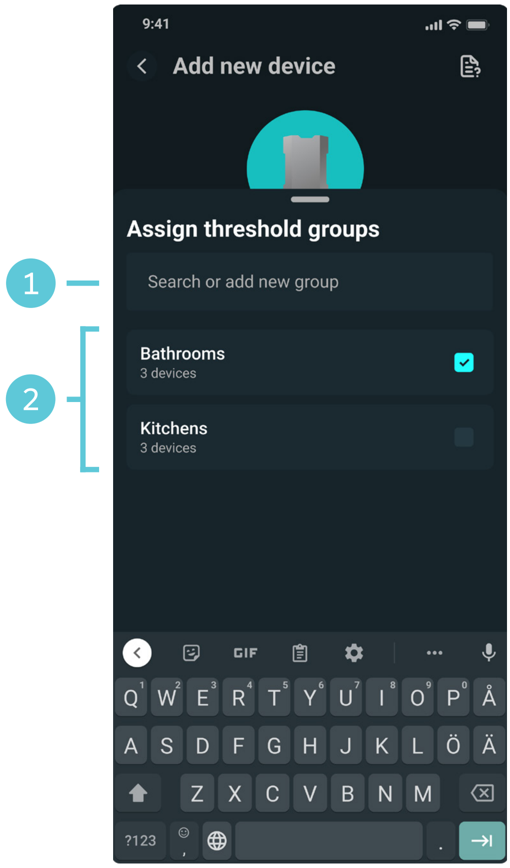

Figure 6.10. *Assign to group*.

The threshold group selection functions similarly to position assigning. Groups can be added or searched for through the text entry (1). Already added groups are collected below (2). A difference is that the selection consists of check-boxes, to accommodate selecting several groups. Since users could want several different thresholds to trigger an alarm on certain devices, a device should be able to be added to several threshold groups.

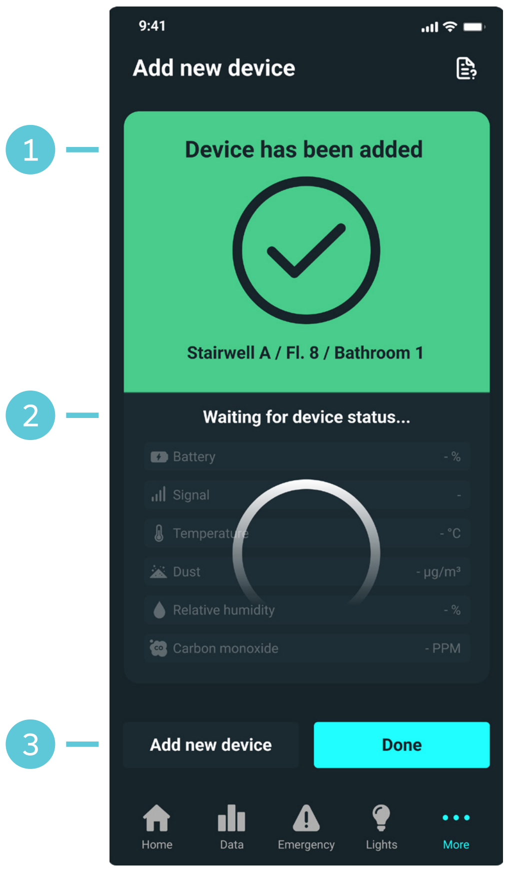

Figure 6.11. *Loading screen*.

After having entered information and pressed the add device button (figure 6.4), the user is taken to a feedback page. The user gets feedback that the device has been added (1) and an indication that the device is retrieving the device's status (2). The user has the option to leave the page or add a new device (3).

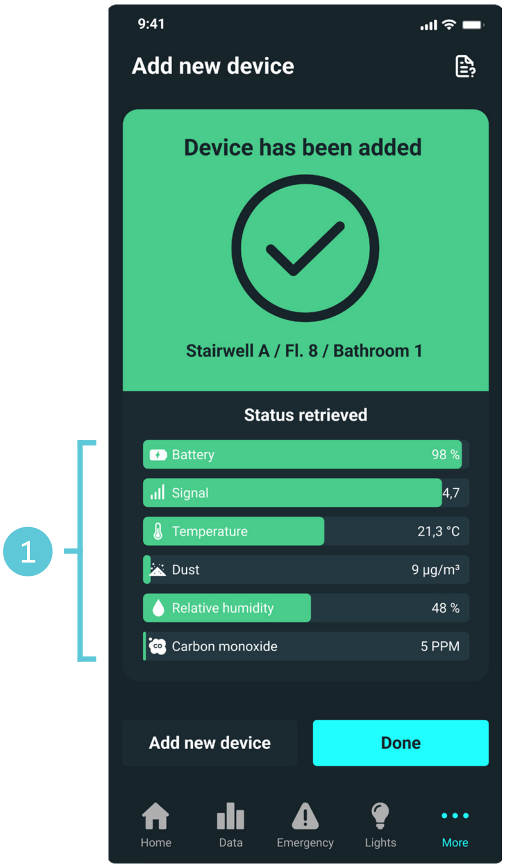

Figure 6.12. *Status retrieved*.

When the status has been retrieved from the device the user gets an immediate status (data) reading (1). This accommodates the requirements regarding providing immediate feedback on whether or not the device functions properly. Instead of only providing the user with a message that confirms the successful setup, the data reading is actual proof of both the fact that the device is active, and that it can successfully send data to be retrieved by the app. This is in line with the three levels of feedback brought forward by Norman (1992). The feedback of the act itself is provided through the feedback text that the device has been added immediately after the user's action. The intermediate results are provided on the device in the form of lights that communicate the start of set up and the final outcome is provided by the updated status in the app, indicating that the device has been able to successfully send data. This leaves the user no room for uncertainties regarding the success (or lack thereof) of the set up procedure. As Norman (1992) remarks is often the case, the final outcome is not necessarily available immediately. To limit the time for data retrieval, the design suggestion incorporates an initiation of the data retrieval process already at scanning of the qr-code when the individual device is defined. This means that the data retrieval process can continue in the background while the user assigns position and threshold group, eliminating or limiting the waiting time once the user reaches the feedback page.

6.6 Summary

The most notable findings from research includes that the current user segment wants Brinja to perform the initial set up of devices but that being able to use the already entered location data to relocate devices would provide added value as the optimal device placement changes. An important consideration for the set up procedure is that many devices are often installed in a row, resulting in a need to streamline the procedure and eliminate frustration as a result of repetitive actions. Including all information entry on a single page and keeping previously entered information when adding several devices, was found to be an effective solution as it limits the need to remember and enter previously added information. It was also found that all steps necessary to perform for a device to be in a fully operational state should be included in the set up flow. The addition of threshold groups and feedback with a data reading in the set up flow eliminates the need for additional navigation to add information or confirm operational state after set up. Providing feedback in the form of an actual data reading, shows that all steps necessary for functional operation have succeeded, something users found reassuring. The suggested procedure for setting up new devices include scanning of a QR code to define which device is being set up, assignment of location and optionally assignment to threshold groups. When this information has been entered the user is presented with a feedback page together with the status of the device. This design suggestion allows the user to easily add devices by themselves and to relocate existing devices without the help of Brinja.

7. Results: Data visualization

This chapter presents the results of the focus area of data visualization in relation to the aim of establishing how data is currently used and connects with existing processes as well as how it can be improved for situation awareness and task performance for the varying users. It includes the findings from the conducted research, the design specification, concepts generated during the process, the evaluation results and the final design suggestion.

7.1 Research findings

Large portions of the focus area of data visualization can be understood from the perspective of situation awareness. In many instances the data visualization acts as a device for generating awareness of the situation on the site. Users expressed how they use the collection of data to get an overview of states at the construction site. For example identifying an anomaly in the data, such as a lower temperature, to find a floor in the building with an open door. It can also act to create situation awareness for processes and quality surveillance. For example regarding the concrete hardening processes, where users expressed that they access the data to get an understanding of how the newly poured concrete starts to increase in temperature as the hardening process begins. As generating situation awareness is an essential part of the current app and evidently one of the most useful aspects of the data today, it is important that the app effectively supports perception, comprehension and projection for all users.

The current app design provides the data in a data-centric structure, where it is organized based on the internal structure of the data model (devices structured on floors and towers). The research has indicated that this structure is not always task conform, i.e. it does not effectively support users' task performance in their specific role. While most data necessary for creating situation awareness is possible to access in the current app, it is not optimally structured for the users' task performance. For example in the case of identifying an anomaly in the data, the user has to individually enter each tower and floor to see data from specific sensors. The first level of the menu structure only presents averages for the towers, without the opportunity to see the spread of data and thus anomalies. Furthermore, user studies have indicated that the current structure has sometimes been found to be slow to navigate.

Structuring the data in a manner which better supports the tasks of users, and their respective situation awareness needs, was identified as an important goal with the redesign. However, another major finding from the interviews is the breath of needs that exist. Different users have very different tasks at the construction site, translating into different needs from the app. The data and information required to perform their tasks varies, as do their experience with reading and processing large amounts of data. This results in a need to make sure that users which only require a specified subset of data are not presented with excessive amounts of other irrelevant data. One user expressed this as filtering of information being the most important aspect with apps like Brinja's since everyone wants different things. Further, the user expressed that everyone benefits from the information but that a lack of filtering results in people being discouraged from using it.

Through the interviews a number of major task categories were identified. These have been summarized in table 7.1, together with the main user which would perform it and factors of importance for task completion. All of these have been identified as tasks which should be supported by Brinja's app as an effective implementation of each has the potential to improve user situation awareness and work efficiency. The distribution of these tasks is irregular. Some users are highly specialized and would only need a fast overview of specific data for completion of one of these tasks while others would perform almost all tasks and need more extensive data. However, the interviews showed that both specific and broad users would benefit from a form of filtering where the information becomes gradually more detailed in deeper levels of the interface. Some information should be prioritized and accessible early on without the need to navigate menus to find it. This includes threshold or goal reading for process initiation, since people responsible for process initiation are often only interested in that information and should therefore be spared navigation through other data. Threshold reading for remedy, such as closing a door, starting a fan or installing measures for improved work environment, should also be presented early on and be salient. The reason for this is that a failure to acknowledge these data points can have severe human safety and economic consequences. The same goes for identification of an anomaly in the data.

Process and quality surveillance was acknowledged by the interviewees as tasks which could require more complex navigation in the interface. The reason is that only few users would be responsible for this task and they are experts which could be expected to learn to navigate the interface and understand more complex functionality. It's relevant to acknowledge that it was users who would be responsible for this task that requested such a prioritization of information. They highlighted that, while important for themselves, this information would hinder the efficiency of, and acceptance from, other users. Therefore, they argued, the largest collective value could be achieved if this data was scaled back from early view.

Time planning stands out as it is one of the tasks which to some extent applies to everyone who uses the data but at vastly different scales. Some users need to plan their own work and when they can initiate the next work task. They essentially only need to know a date or time when everything is ready for initiation. Others need to plan for process control such as implementing concrete heating to decrease hardening time during cold weather. This requires an understanding of changes of external factors over time and the subsequent response of internal processes (eg. how concrete hardening time responds to change of season from autumn to winter). Other users need a more holistic understanding of processes for time and resource management. For example how different processes are temporally dependent on completion of others for overall scheduling (eg. scheduling workers for mold removal when the correct concrete strength is achieved).

The research also showed that the users have highly developed mental models for the processes on the construction site and the input-feedback properties of the system. The data currently available in the app is used as input where it is interpreted with existing mental models. The highly developed mental models also act to suppress risks related to misinterpretation of data. Users actively engage in measures to limit the effects of measurement errors and understand how external factors impact data. For example concrete sensors are actively placed in a corner of the building with the worst conditions for hardening (eg. in the most shadowed or coolest area) so that worst case scenarios are covered.

Table 7.1. User tasks, main users *and important factors*.

Task	Main user	Important factors
Threshold (goal) reading for process initiation	Supervisor (responsible for process initiation), construction worker	- Fast access to readiness state - Overview of values reached for house part and floor

Threshold reading for remedy/measure (eg.work environment, concrete heating)	Supervisor	- Warning before threshold is breached - Difficult to miss - Easy to find place of breached threshold
Time planning/ management (eg. schedule employees when tasks are planned to be performed)	Site manager, supervisor	- Overview of values reached for tower and floor - Projection of future status (determine trend)
Process and quality surveillance (sometimes with remedy/measure and sometimes for projection of future concrete pour)	Supervisor	- View of development over time
Identification of anomaly	Supervisor	- Easy to identify anomaly - Fast access
Data export	Supervisor, QEHS	- Possibility to export chosen data subset
Backtrace data (learn from mistake), summary of data at end of project	Supervisor, site manager, QEHS	- Easy to find and view all data
Control of unit function, troubleshooting	Brinja expert user	- Immediate data reading at installation

7.2 Design specification

The research resulted in a design specification which can be seen in full in appendix F. This section summarizes some of the most important requirements and guidelines.

Overall, the research uncovered a number of tasks which should be effectively supported by the data visualization and a need for efficient navigation in the interface. This resulted in requirements and guidelines stating that the time to reach a desired diagram should be minimized, that the necessary steps to desired information should be minimized from all parts of the data tab and that filtering selections should remain for the next time the user enters the interface. A demand for easily switching between different time frames in the diagrams, found during interviews, resulted in a requirement to allow users to be able to switch between appropriate graph timeframes with only one click in order to increase the efficiency of the use. Furthermore, it was found that users of concrete sensors mainly use a time frame of 28 days, as much of the hardening happens during that time. They also expressed that they wanted to easily compare the graphs between different concrete sensors to see for example if the progress of one is lagging behind. These two needs lead to a requirement of providing users with concrete sensors a merged 28 days diagram showing all concrete sensor graphs starting from the day of installation.

Users who have concrete sensors also mentioned that they would like to get notifications on when a sensor has reached a specific value. This is so they could get information about when the next step of the process can get started. Hence, the solution should notify the user when next steps in processes on the construction site can be initiated. Furthermore, in order to support the task of planning of processes and resource allocation a requirement to provide projected estimates of when a process will be finished was included.

The findings regarding the large variations in user tasks in relation to the expressed need to prioritize information based on these resulted in several requirements concerning structure and prioritization of information. An overarching prioritization can be seen in the guideline stating that the design should provide data for global situation awareness early on the data page and data for goal based situation awareness after filtering. Further specification includes that an overview of data values reached for house part and floor and anomalies therein should be fast to identify without searching or navigating deeper levels of the interface. Requirements that safety critical data points as well as estimated time to process completion should be provided on the first reached data page without further navigation, were also included based on interview findings.

Furthermore, in order to provide users with critical information in a timely manner without the need to constantly check in with the app and deplete resources for other tasks, a requirement stating that users should get a notification when a threshold is surpassed was included. Once in the app it was specified that visualization of a threshold breach should be visually salient and stand out among other data and that time until comprehension of a safety critical data point should be minimized. These requirements were included to further specify prioritization of information based on importance of tasks and severity of potential failure to identify the data.

7.3 Concepts

For the data visualization two different concepts were developed for evaluation. They will be presented in short below.

Concept 1
The first concept has a shallow menu structure which consists of one layer with the ability to switch between filtering and graphs. The user is first presented with a filtering page where they can select specific sensors and locations they are interested in. Once a selection has been made they can press the graph button to show the selection. In the graph view the user can see both the current data in bar charts and data over time in line graphs. The filtering of time span has been redesigned as a top bar with preselected time spans for fast switching between views. A new diagram view has been included to support users of concrete sensors with comparisons of graphs. In this view all graphs are placed with the same starting point in a 28 day diagram. The concept's shallow structure is highly optimized for speed in reaching desired data. Global situation awareness is supported by the goal and threshold indicators on the filtering page. Concept 1 is seen in figure 7.1.

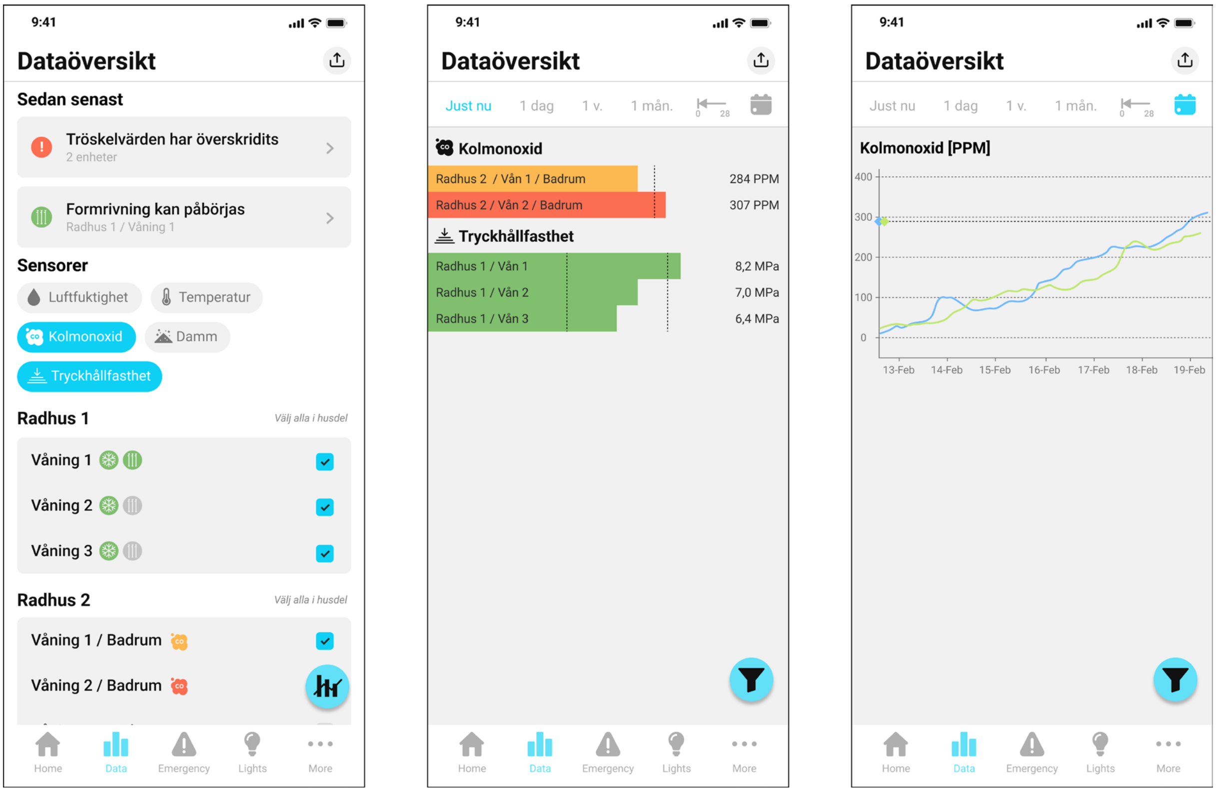

Figure 7.1. *Data concept 1.*

Concept 2

The second concept has a menu structure more similar to today's app with a first level where the user can see data from and select the house part. Once a house part is selected the user is taken to the second level where the user can see data from and select floor in the house part. The last level shows line graphs with data over time from the selected floor. The data visualization on the first two levels consists of bar charts. In the charts all devices are indicated with lines in the bar to allow users to see the spread of values. The highest and lowest values in the spread are written out on each side of the bar. The last level containing line diagrams has the same new features as concept one. This design is highly optimized for global situation awareness and fast identification of anomalies. Concept 2 is seen in figure 7.2.

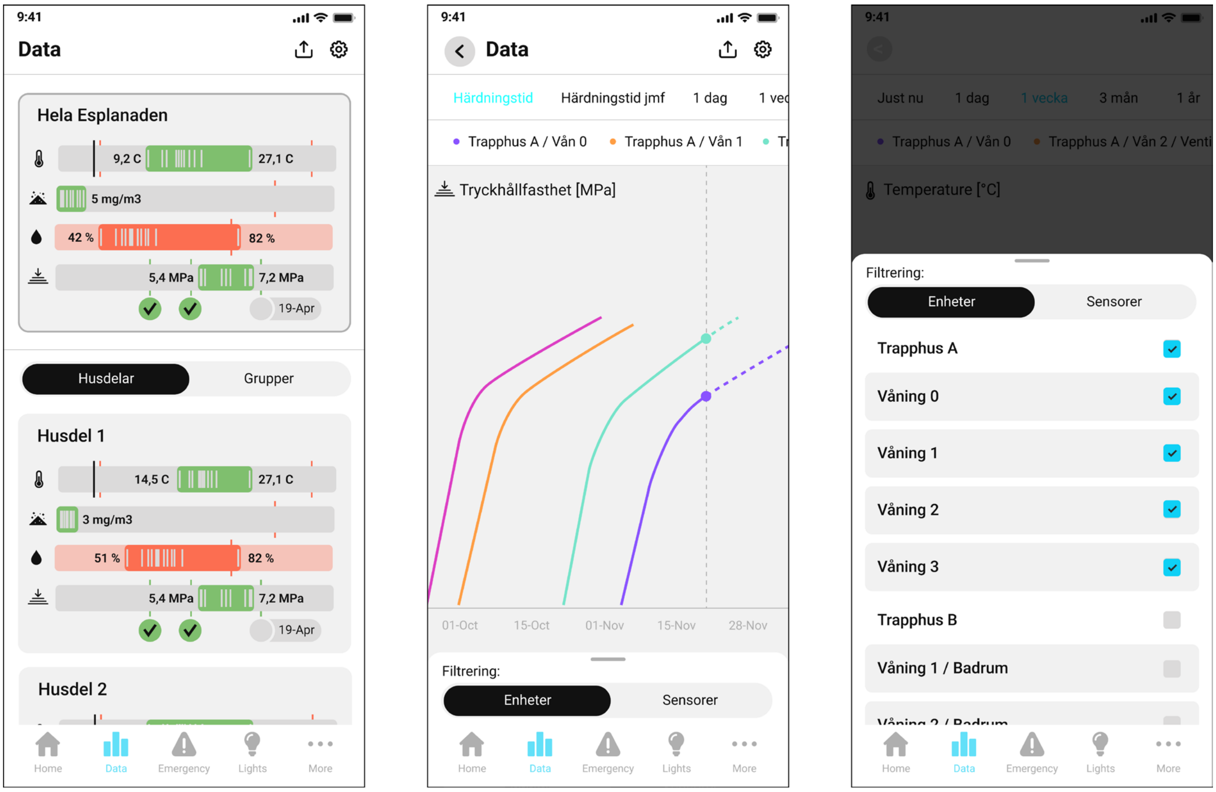

Figure 7.2. *Data concept 2*.

7.4 Evaluation and feedback

During evaluation of the two concepts a majority of the users preferred concept two over concept one. They highlighted that the concept provided an overview of a large amount of useful data and had an appropriate filtering of detailed information based on location (this was also familiar from the current app design). Many interviewees said that the ability to see the spread of data from the house parts gives a faster overview of states at the construction than the current app. Users of concrete sensors were very positive towards the new functionality of goals. The visualization of goals in concept two, including a date with projected goal fulfillment, was appreciated and expressed to support both overview, planning and the task of identifying where a process can be initiated. As one interviewee put it:

> – This is awesome. This is what we want to see when we are casting, that negative temperature doesn't affect the concrete negatively, 5 MPa and then around 8 if you are making a wall since you can tear down the mold and then it's shoring after that and approximate time when you reach this. That's awesome. [translated]

This quote also highlights that the user's mental model in relation to the concrete process supported interpretation of the goal visualization and what the goals correspond to even if no text explanation was provided. Showing two goals on a compressive strength graph was enough for the user to understand what the goals represent. One user expressed the goal visualization as considerably reducing the need to think about and analyze data yourself, as the app does the necessary calculations for you.

Once presented with this new functionality, two users identified a further development in adding a notification when the hardening process is slower than a specified reference.

One user highlighted that the scale of the bar charts is important since an appropriate and locked scaling can aid even faster reading of states. The interviewee expressed how the user could then look at only the bar and see where on the scale it is located. This location would tell them how far the process has proceeded without even needing to read the number values. The interviews also showed that the bar graph could be interpreted as a temporal progress bar where useful, i.e. that the placement of the bar would be processed as corresponding to a time to completion. This is related to the concept of representations in cognitive ergonomics. However, in this case there is an additional step in the processing of the representation. The bar chart is a symbol that represents the compressive strength of the concrete. But the evaluations highlighted that users would process the symbol as not only representing compressive strength but also time. The reason is that current compressive strength is directly correlated with how far the hardening process has progressed and therefore how much time remains until the process is finished. The users made this interpretation intuitively without external help. This indicates that the bar graph is highly functional together with users' mental models of processes, and that it supports both quality surveillance and time planning tasks.

The evaluations also uncovered negatives with concept two. The largest issues were related to guessability and initial understanding. Many interviewees found it difficult to grasp what certain parts of the design represented. Firstly, the different sensors were only indicated through symbols, not text. This meant that users who had not previously seen the symbol could not understand which sensor the symbol corresponded to and therefore what was being measured. Secondly, almost all users understood that the bar graphs represented a span of values, but users had issues interpreting which span (eg. users asked if it was a span over time or a span of different devices). Lastly, the meaning of the lines indicating the spread of data for different devices was difficult to understand. After these concepts had been explained to the interviewees they had no issues reading and interpreting the data, indicating that the problems were mainly related to guessability and first time interpretation.

Two interviewees preferred concept one over concept two. They expressed having tasks that dominantly consist of line graph usage, for which concept one is considerably faster while also containing less distracting other content. One of the users expressed the need to make highly specific selections of devices to show data for. For this purpose, concept two is suboptimal since it, like today's app, requires the user to go through several menu levels until graphs for one floor are shown and then change the filtering until more desired devices are shown in the graph. There is also a risk that the workflow in concept two results in frustration from the need to essentially redo filtering selections. For this specific task the user first narrows down the selection to one device and then has to override some of the narrowing by selecting devices which had just been filtered away to show again. This evaluation finding can be connected to a low perceived usefulness (relating to speed and effectiveness) for these specific types of tasks in concept two. These evaluation findings resulted in a merge of concept one and concept two for the final design suggestion as to efficiently support all types of users.

The design of the graph page was similar for both concepts and also appreciated with little negative remarks from interviewees. All users were positive towards the new filtering of time span with predefined selections. Users of concrete sensors specifically appreciated the 28-day view which provides fast access to the graph view most often used in the industry. They said that a comparative view where all concrete graphs are compared on the same time span from their first day to their 28:th day is the most useful. This view, they said, could be used to see how the hardening process changes over time. For example they can follow how the seasonal change in temperature impacts the process by comparing a concrete pour made a month ago with a current one in the same diagram. This would aid planning of initiation of measures such as concrete heating and give an overall situation awareness of processes in relation to each other and external factors such as weather, according to interviewees.

7.5 Design suggestion

The final design suggestion for the data tab consists of three separate pages or views which are immediately accessible (from anywhere in the data tab) through one click in a menu located in the page header (see figure 7.3). The page header menu is consistent with one already used in the lights section of the app and thus constitutes an addition which users are likely to already be familiar with. The three pages in the menu consist of the current data readings, graphs of the gathered data over time, and the progress of goals. The fact that both the current view (stemming from concept 2) and the graphs (stemming from concept 1) can be accessed immediately means that the workflows of both types of users identified in the evaluations can be efficiently accommodated. The user's last position in the menu structure is also saved for the next time the user enters data, meaning that users which only use graphs would theoretically never have to enter the other pages after the first time. This further streamlines the experience and could give the user an impression of an interface highly customized for their needs. The goals page has been added since the development of the two concepts. The purpose is to improve the preconditions for easy understanding and efficiency for the specific user group that would only need to know about goal completion for their work tasks. This is in line with the research findings concerning filtering out only necessary data for user groups which only need a subset of data for their tasks. However, the visualization of goals is still accessible in the current page to support users who need more complex information for their tasks to acquire global situation awareness without navigating several pages. The flow for the data visualization is showcased in figure 7.3.

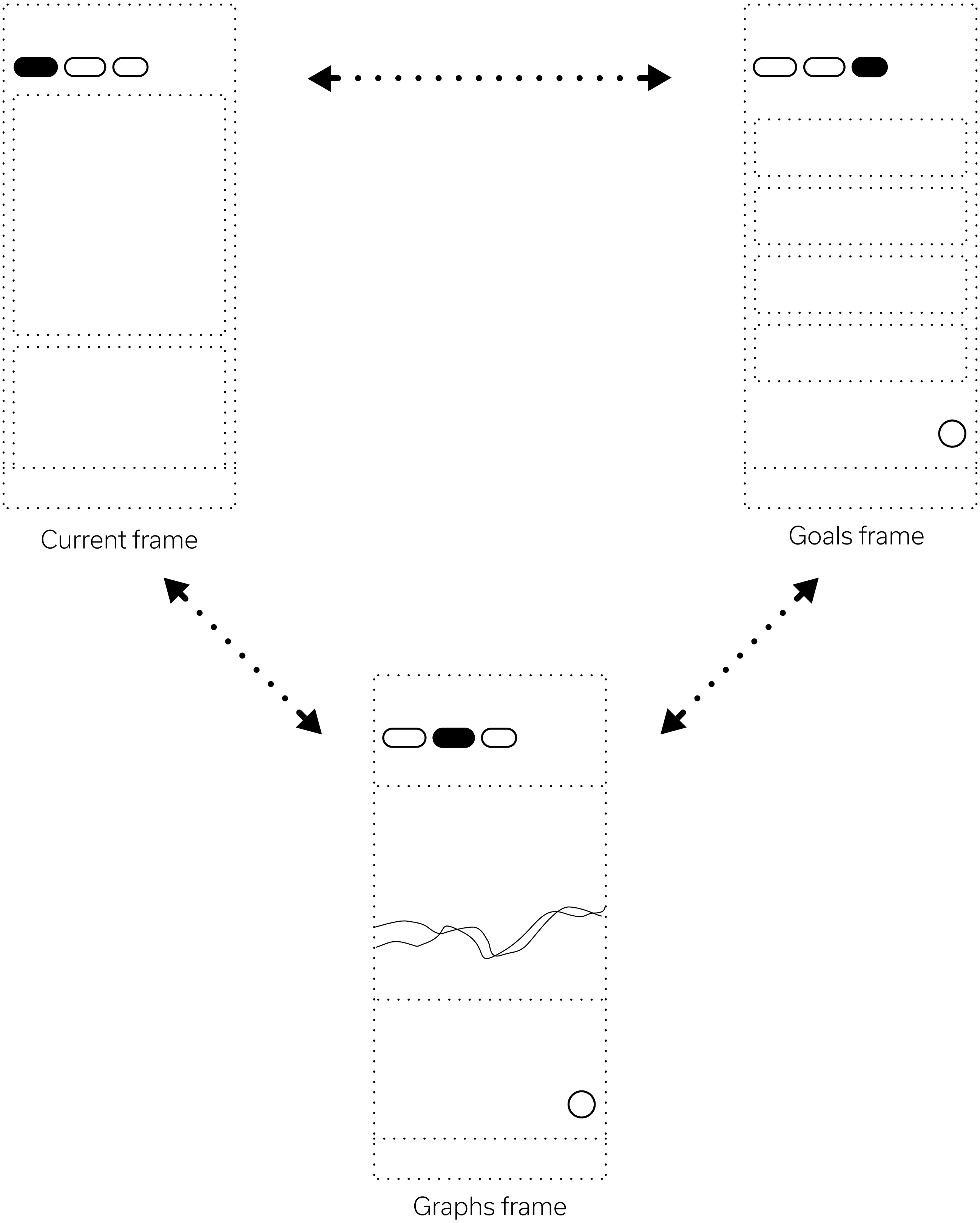

Figure 7.3. *User flow of data visualization.*

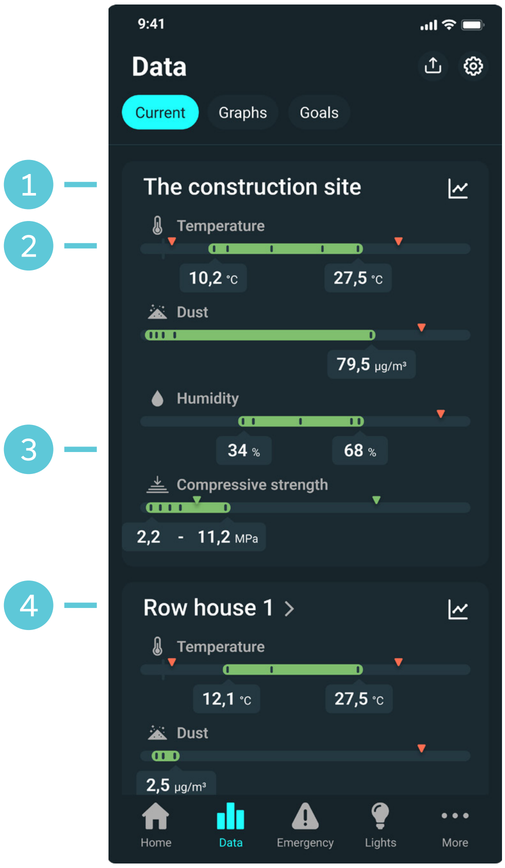

Figure 7.4. *Current page 1*.

The current page consists of an overview of all data from the latest (current) data reading of each device. It presents the data as spans within the whole construction site (1) and the different house parts (4). The span incorporates the lowest current data reading of any device to the highest current data reading of any device. To be able to see the distribution of data within the span, each device's data point is marked with a dark line (2) within the bar. This makes it possible for users to efficiently identify an outlier in the data (consider the reading for dust in figure 7.4 and thus initiate a potential remedy.

The data value of the highest and lowest device within each span is visualized below the bar (3). These two values define the entire span of all data points meaning that the user can acquire global situation awareness regarding the spread of data. If these two values are within acceptable bounds all other values are too.

Furthermore, the highest and lowest value provide the user with context for interpreting the value of other data points. They provide a scale for the span in a bar graph which lacks an inherent scale (not incorporated due to visual complexity). This means that an approximate understanding of all data points in the span can be read out from their relative position in relation to the highest and lowest value. The result is a powerful data visualization where large amounts of global data can be read out from a graph with a relatively low level of visual complexity.

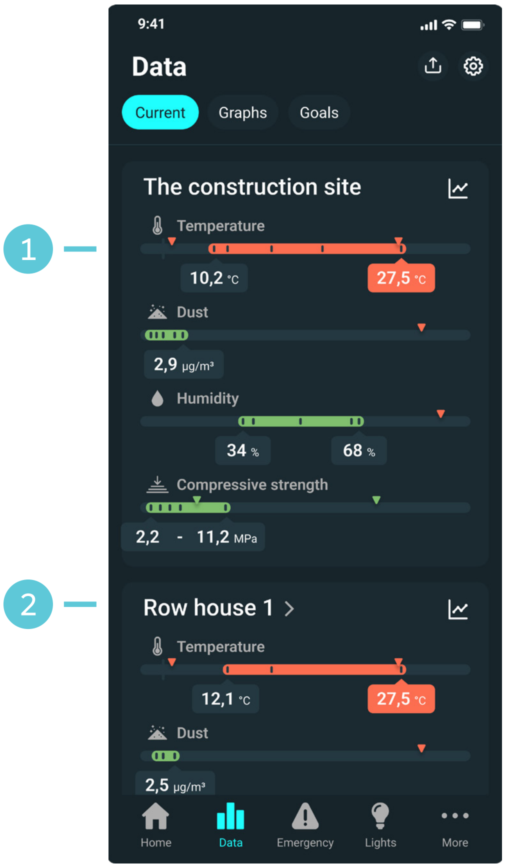

Figure 7.5. *Current page 2.*

The thresholds and goals set by the users are visualized as red and green arrowheads on top of the scales.

If a device measures a value that is higher than the device's set threshold, the green colored range of the measured data turns red to highlight a threshold breach (1). The data value constituting the breach also turns red. This salient visualization enables very fast identification of threshold breaches. It is specifically useful when scrolling through the page, if there are many house parts. Instead of having to stop at each house part and interpret the data, the user can simply scroll and search for a red bar, which is easily identified even when scrolling fast.

The design suggestion incorporates a locked scaling of the bar charts. As mentioned in 7.4, this means that the users can use the position of the bar when interpreting the data.

The data for the whole construction site or either of the house parts can be plotted in a graph by pressing the graph button for the corresponding field (2). This takes the user to the graphs page with the filtering corresponding to the whole construction site or the respective house part. This supports a workflow where global situation awareness is acquired in the current page after which further inquiries into details of the states can be accessed in the graphs.

Figure 7.6. *Current page 3.*

By pressing a card corresponding to a house part the user is taken to a view of that house part fractionated into its floors. The structure on this page is similar to the previous one with each floor having a card on its own. However, this level of the interface is deeper than any previously incorporated. It consists of first the selection of data in the bottom navigation bar, then the selection of current in the top navigation bar and then the navigation into one of the objects under current. In order not to result in confusion the layout of the semantic grid is vital. In line with Rosenberg (2020) the larger scale interaction menu in the header is maintained to together with the main header support the user in understanding their current position within the large scale menu structure. The indication of local navigation is solved through a header field in the page body that specifies the entered house part and allows the user to go back. The placement in the page body together with the floor cards makes this field subordinate to the large scale navigation in the header which is to aid the user's understanding of the hierarchy of the structure.

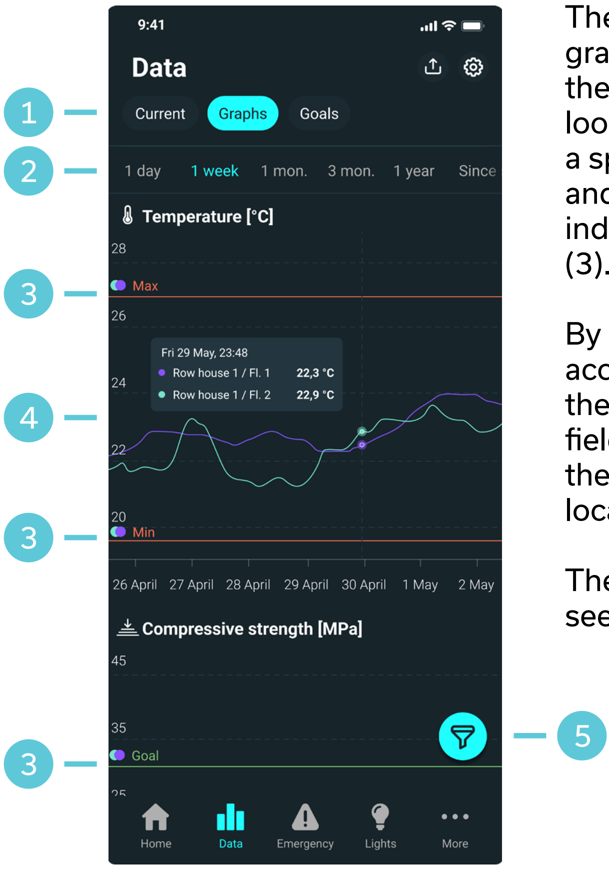

Figure 7.7. *Graphs page 1.*

The graph page can be accessed through the graphs button in the header menu (1). Right below, the user can pick a time frame that they wish to look at, with periods such as 1 day, 1 week, and a specific start and end date (2). The thresholds and goals are visualized as horizontal lines with indicators for which graphs they refer to on the left (3).

By holding anywhere in the diagram the user accesses a data field (4) which shows the value of the different graphs at the corresponding time. This field also acts as a legend to differentiate between the colors of the different graphs and which location they correspond to.

The filter button (5) opens an overlay which can be seen in figure 7.9.

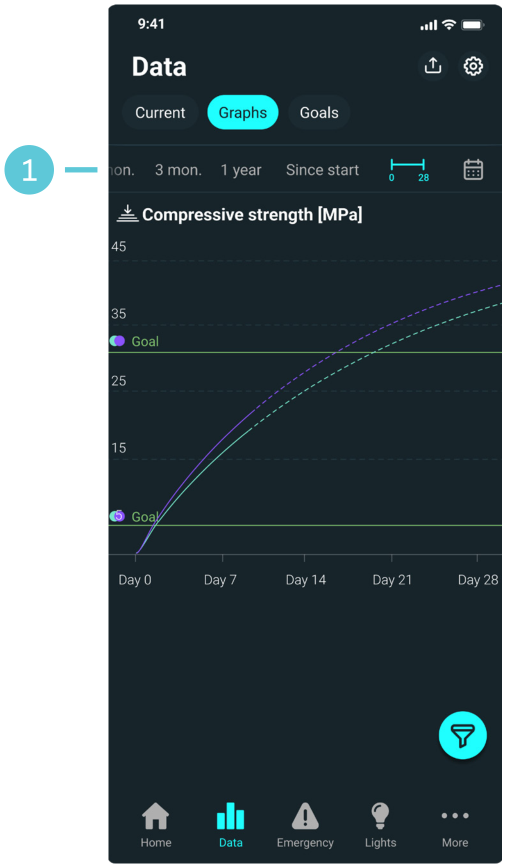

Figure 7.8. *Graphs page 2.*

The comparison view for concrete sensors is one of the selections available in the time selection (1). This option will only be available in projects which have concrete sensors. It places the graphs in a 28 day view where all graphs start at zero regardless of their actual starting date. For a concrete sensor which has been installed for more than 28 days, the full graph will be shown. For one installed less than 28 days ago the line will follow the measurements until the current day, and then a dashed estimate will take by (for compressive strength). The dashed estimate will be based on the concrete model and either estimated temperatures or average temperatures for the time. This functionality gives the users improved possibilities for time planning and specifically a tool for comparing data over time to understand and compensate for how external factors influence the hardening process over time.

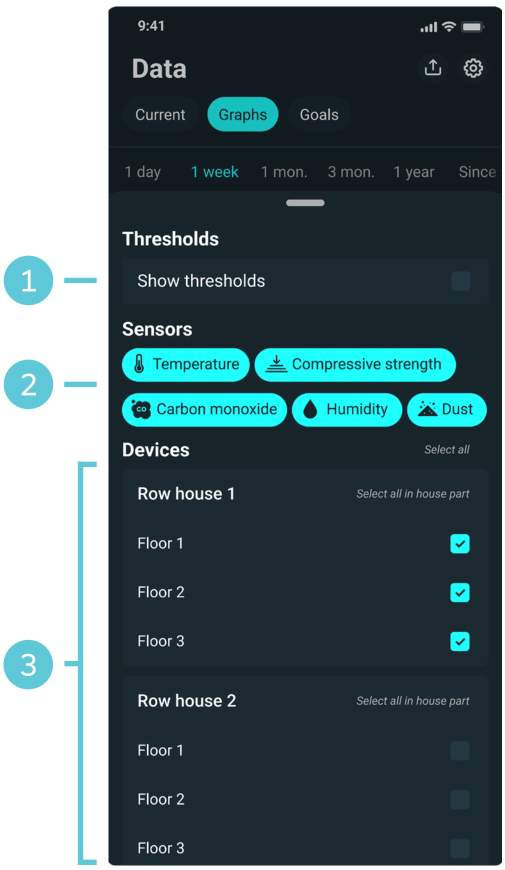

Figure 7.9. *Graphs filter.*

The filtering allows the user to select if thresholds shall be shown in the diagrams (1), which sensors shall be included (2) and which devices' data should be shown (3).

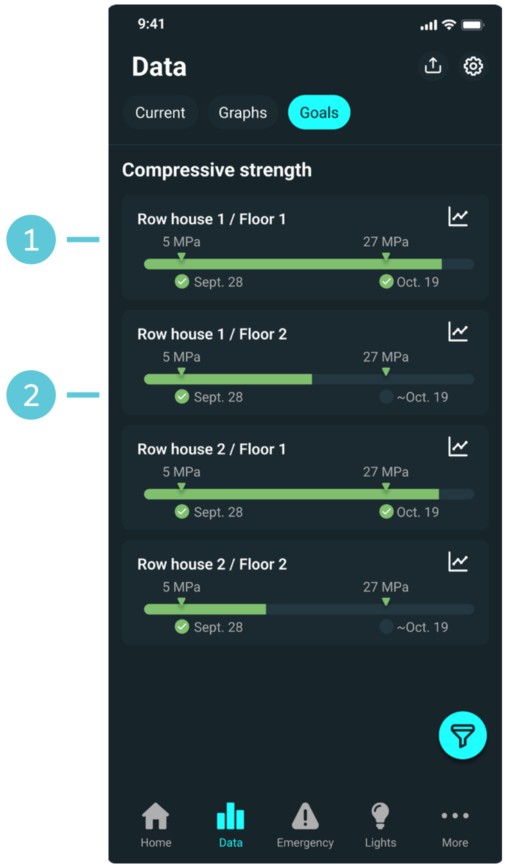

Figure 7.10. *Goals page*.

The goals page contains cards which present the data of different devices separately. The data is displayed as a bar chart which gradually rises. The different goals are displayed as arrowheads similarly to the current page. Each goal also has a text indication of what value the goal corresponds to (1) and an area below the goal for indication of completion or estimated completion (2). The estimated completion date aids planning of processes such as initiation of mold or shoring removal. The graphical illustration in the form of a bar chart is designed to aid fast estimation of progress and support the processing of compressive strength graphs as corresponding to time to completion.

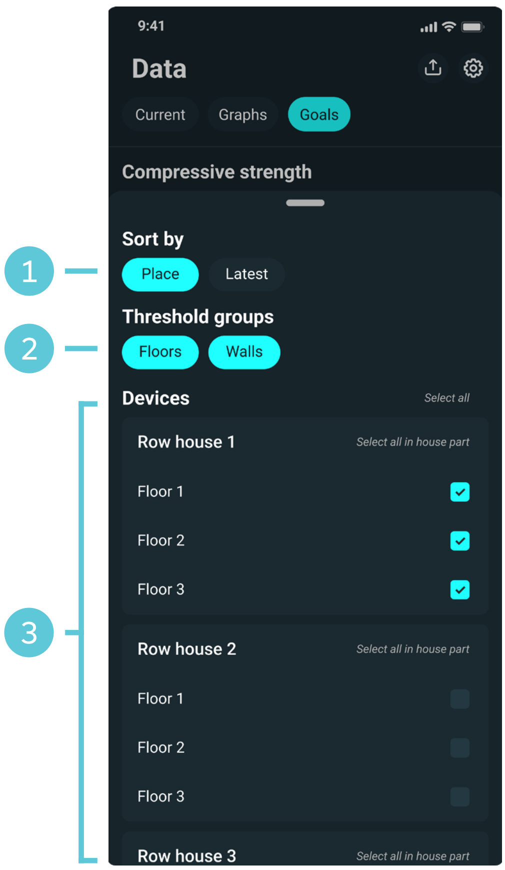

Figure 7.11. *Goals filter*.

The goals can be sorted either based on place or in the order of installation of the devices (1). The user can filter which goal cards are displayed based on which threshold groups the device is assigned to (2) and solely based on device (3).

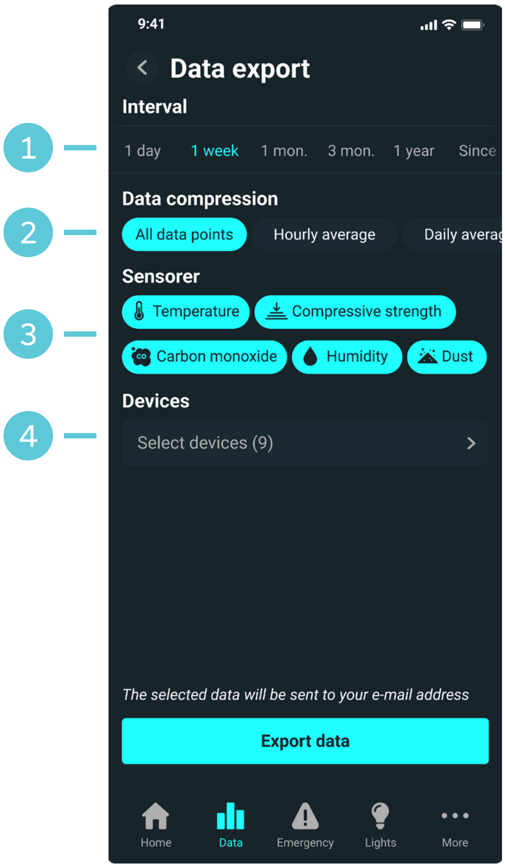

Figure 7.12. *Data export*.

The data export page is accessed in the top right corner of the data tab. Here the user can filter which data they want to export. The filtering options consist of interval (1), data compression (2) or the frequency of data points exported, sensors (3) and devices (4). The filtering will be preselected with the current filtering on the page the user was using before entering the data export.

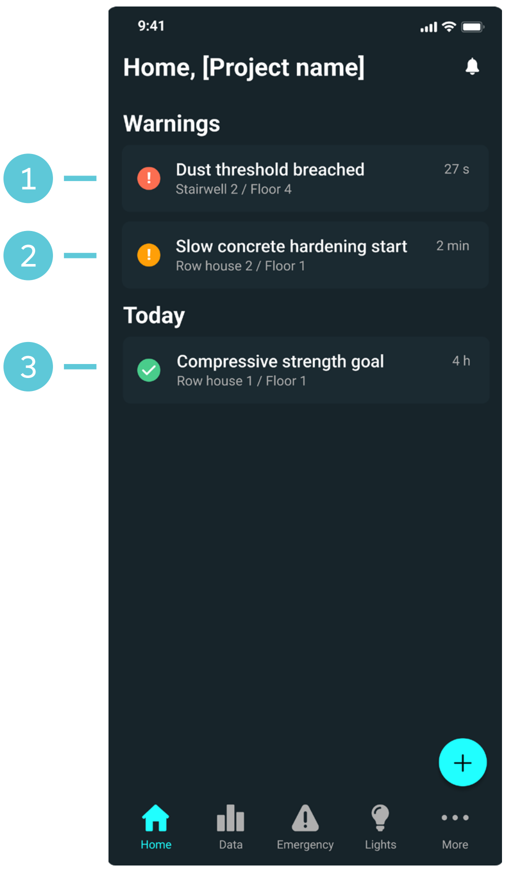

Figure 7.13. *Home page*.

Data events that trigger notifications will be automatically shown on the home page, in line with requirements regarding immediate access to certain critical information. These include threshold breaches (1), slow concrete hardening start (2) and goals reached (3). Threshold breaches and slow concrete hardening starts could require immediate remedy. The design suggestion therefore incorporates them in a high priority section at the top of the home page. These will always be shown above anything else but they will only remain for as long as the preconditions for triggering the notification is fulfilled, i.e. if the values return to acceptable levels the warning disappears. Goals require no immediate action and are therefore suggested to be placed in the regular feed of the home page with the most recent event at the top. In order to limit the risks for automation bias, all notifications have been phrased as information regarding the state rather than as a call to action. For example “compressive strength goal” as opposed to “begin shoring removal”. As such, although the notification immediately informs the user about a state for action, it requires the user to process what needs to be done themselves.

7.6 Summary

The most notable findings from research include that the current use of data concerns the generation of situation awareness regarding overview of states and anomaly identification as well as process and quality surveillance, something which is particularly important for concrete processes. It was found that the data from Brinja's app was an incorporated part of processes on the construction site as an input for processing of current state, projection of future state and the decision making regarding remedy and process initiation, but that the current data structure does not always effectively support these purposes. A user interface design with the ability to see an overview of the current data readings, a detailed graph view with data over time and a view for goal and process progression was found to effectively meet the needs in relation to all identified tasks. The overview, consisting of bar charts with individual device readings indicated within the bar and the highest and lowest values presented, enables the user to efficiently generate global situation awareness regarding anomalies, threshold breaches and process progression without navigating several pages.

The concrete hardening process was found to result in complex interdependencies where the hardening progression is impacted by external factors such as temperature which can require control measures to be put in place and where process initiations, and therefore scheduling and resource allocations, are dependent on the hardening progression. A 28 day graph view where different concrete castings can be compared on the same time frame was found to be an appropriate tool for generating understanding of changes in concrete response over time and for process planning. Furthermore, the introduction of goals and estimated times for goal completion increases efficiency by limiting the need to analyze data for resource and task planning.

8. Results: Set up new project

This chapter presents the findings from the focus area of setting up new projects in relation to the aim of enabling users to individually set up projects while providing them with a positive initial experience and lowering the threshold to start using the app. It includes the findings from the conducted research, the design specification, concept generated during the process, the evaluation results and the final design suggestion.

8.1 Research findings

The purpose of allowing users to set up their own projects is mainly to allow sales of devices over the counter instead of having to be in personal contact with Brinja. Therefore the main users are not necessarily the construction workers who are currently Brinja customers. These customers have already found the current procedure for becoming a customer and also, to a large extent, appreciate this way. Therefore many interviewees expressed an indifference to the addition of this functionality. Due to this they also had no strong opinions about what it should include.

For a project to be successfully set up certain information from the user is necessary. First and most obvious the project needs a name to be distinguishable for the user but also for Brinja to have insight and be able to identify projects (eg. for customer support). The company responsible for the project and the project's address is also beneficial for identification purposes for both users and Brinja. Furthermore, billing information is necessary for Brinja to be able to get payment for the product and thus allow it to be used.

Results from the interviews indicate that the most likely user for the set up procedure of a new project is a site manager, since they have the large scale responsibility for product acquisition and over the project as a whole. A supervisor could also be a potential user, especially for small scale projects within an already existing construction site (eg. if one would want different operations on site to be divided into different Brinja projects). Although, interviewees saw this as an unlikely scenario.

Since the set up of a new project is largely intended for a new segment there are additional relevant considerations. The users in this segment will not have the same amount of support from Brinja as a current user. Current users get an onboarding session where the app is explained to them with the project already set up and sometimes devices already installed. This will not be the case for this new type of user, for which the set up procedure will often be the first contact they have with the app. Therefore it was found to be beneficial if the set up procedure for a new project not only started the project but also provided some guidance on these matters.
The identified areas necessary for a normal project to function were setting up the project, entering billing information, setting up units and adding new users. Additional guidance to these four tasks would aid the user in getting to a state in the app and a proficiency in its functionality that would correspond to that of a current user after onboarding.

Initial research and later evaluation indicated that these four tasks would not necessarily be performed by the same person. A site manager said that he would likely start the project, add billing information and add one additional user to which he could leave the responsibility of adding new devices and more users to. This shows that including all of these tasks in one set up flow is not optimal since one would have to switch between different users midway.

8.2 Design specification

The research resulted in a design specification which can be seen in full in appendix F. This section will summarize some of the most important requirements and guidelines.

Due to the new customer segment lacking previous experience with setting up projects and also lacking guidance during the set up procedure, a requirement to allow users to set up projects without external information and guidance was identified. This also entailed having high clarity of information entry and clearly showing what task is to be performed by the user. Requirements and guidelines about providing the user with a positive first experience with the app and more specifically enabling the users to learn how to use the set up and to introduce the basic necessary functions of the app to the user were also included.

8.3 Concept

To account for the fact that the same user would not necessarily perform all of the identified onboarding tasks on their own, the concept included most of them after the actual setup of the project. The user is first presented with a set up page where the name, description, company and address is entered. After having performed this short set up the user is immediately taken to the new projects home page, where the rest of the onboarding tasks can be accessed. These are collected in a separate area called project start-up and each item can be pressed to come to the corresponding set up procedure.

8.4 Evaluation and feedback

The concept was positively received during evaluation. The interviewee easily identified how to access the set up of a new project and found the information entry, with exception of one item, to be relevant and easily entered. The one item that the interviewee questioned was the project description, which he said he would not have any use for. Furthermore, he argued, a description is such an open-ended item that it would be difficult to know what to actually enter. The description was also not considered necessary by Brinja and was thus removed in the final design suggestion. Continuing to the home page the user immediately identified that the project had been successfully set up and acknowledged the remaining items in the project start-up checklist. These were found to be relevant and their meaning and purpose easily understood. The interviewee especially remarked on the billing as "highly relevant" but raised concerns regarding how that information would look for Brinja.

8.5 Design suggestion

The final design suggestion includes a recommended flow for accessing the project set up. There are two possibilities for when a user would set up a new project. One is as a completely new user in which case the project set up is included in the introductory flow with language selection and creating an account in the order highlighted in figure 8.1. After completion the user lands on the home page with the new project start-up checklist. The flow has been designed with as few steps as possible to make the procedure fast and unlikely to result in the user leaving. The new project start-up checklist aids a new user with the basic necessary functionality of the app. This is, as discussed before, a measure to counter the lack of a personal onboarding meeting with Brinja. The other option for setting up a new project is as an existing user of the app. In this case the project set up is accessed through either the shortcut plus button on the home tab or through projects in the more tab. The flow for setting up a new project is showcased in figure 8.2.

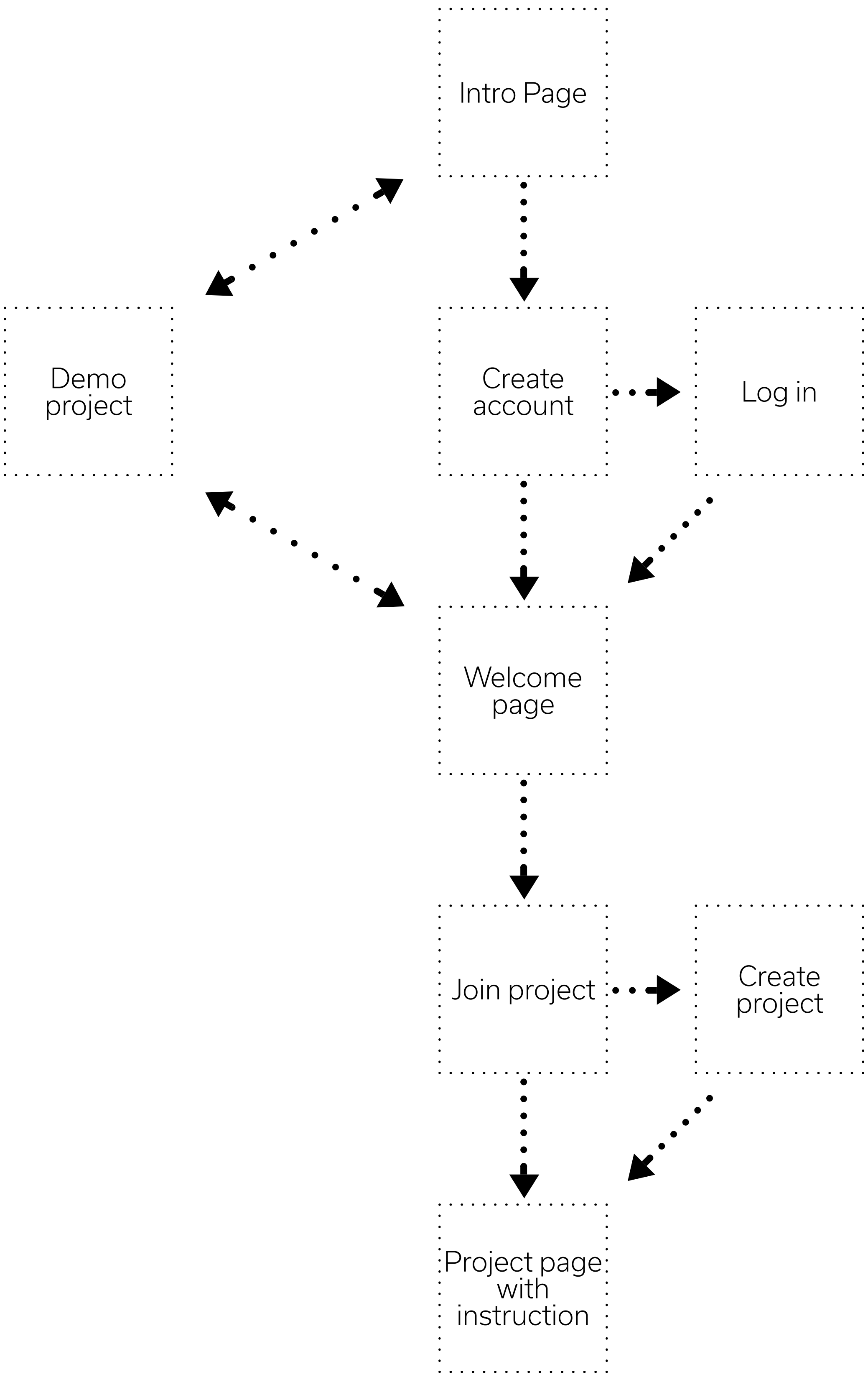

Figure 8.1. *User flow of set up new project.*

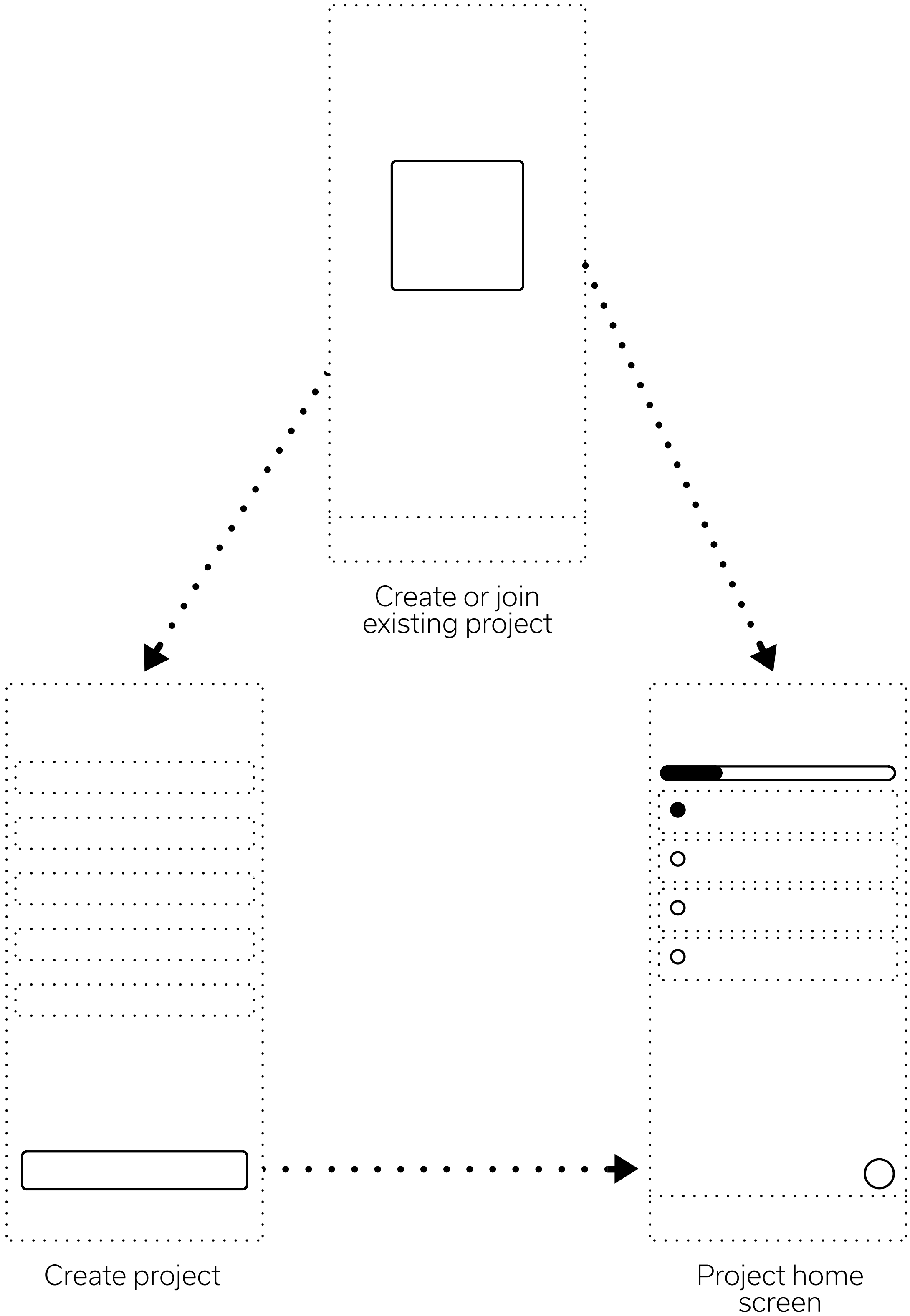

Figure 8.2. *User flow of creating or joining a project.*

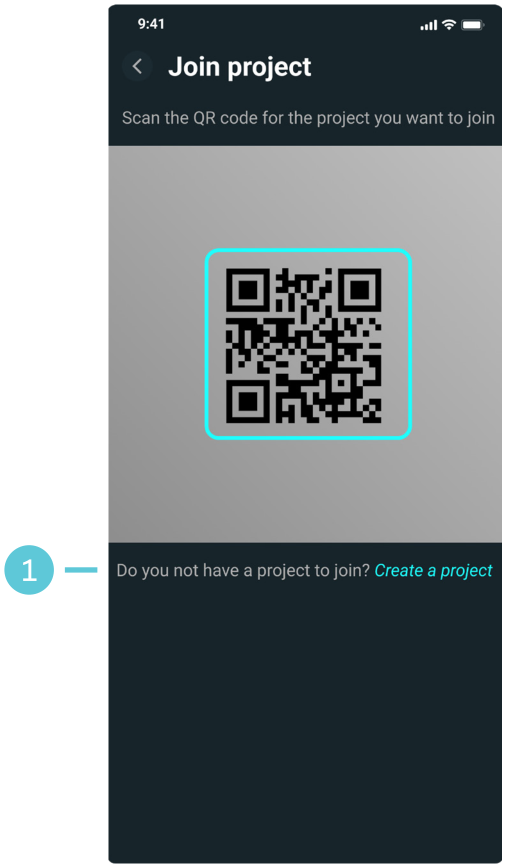

Figure 8.3. *Join project*.

As a majority of users are assumed to join existing projects and not start new, the default for both of these flows are to be taken to a page for joining a project. From this page the user can then press "create a project" (1) to be taken to the page for project set up.

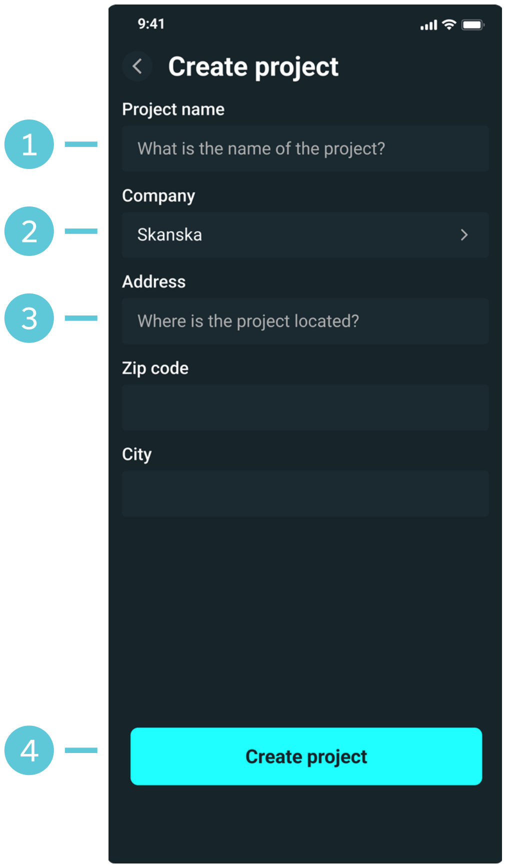

Figure 8.4. *Create project*.

In the project set up page users fill out the necessary information for creating the project; project name (1), company (2) and address items (3). All items are free text entry boxes except for the company which opens an overlay with a list of construction companies to select from. The reason is that this approach eliminates the creation of duplicate names for the same company by different users, e.g. concerning upper- and lower-case letters. The user finishes the procedure with the create project button (4) and is then taken to the home tab of the new project (figure 8.5).

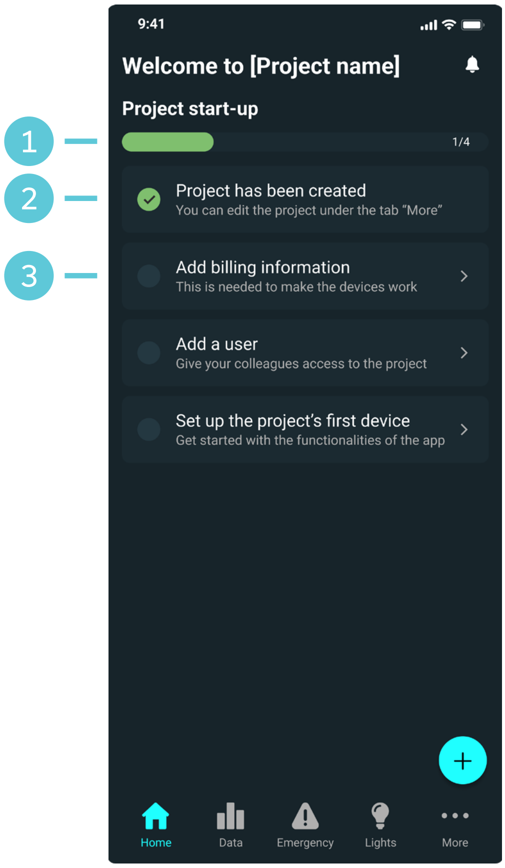

Figure 8.5. *Project start-up*.

The home tab of a newly created project contains the project start-up checklist where the user is guided through the set up procedures. Each item in the project start-up checklist has a header which explains what is to be done and additional text that explains why the task should be performed (3). This is to aid the users own ability to determine what needs to be done and prioritize actions. Since different people could perform different tasks, and there is no inherent difference in priority between the items, they do not need to be performed in a specific order. Each item acts as a shortcut button to the setup of the specific task. Once an item has been performed it gets checked, the progress bar (1) is updated and the text changes to an explanation of how the user can redo the action or change the entered settings later on (2). Once all items have been performed users are free to close the project start-up checklist. It does not close automatically as it can still function as guidance or onboarding information if the user wishes. The start-up checklist also has the added benefit of aiding users who will be in a project started by Brinja like today but that do not participate on the onboarding. They will get the basics from the onboarding presented to them on the home page when they enter the app.

8.6 Summary

The most notable findings from research includes that the main users of the set up procedure will be users from the new segment of over the counter products and that this puts special emphasis on limiting the risk that users exits through only requiring necessary information to be entered and on introductory functionality that can replace in person learning sessions. It was also found that the tasks required for a project to become operational could be performed by different people and that providing many of the tasks as an option after actual set up of the project is therefore beneficial. Technology mediated scaffolding in the form of a project start-up checklist is proposed as a means to provide users with a proficiency in the necessary functionality for a project to become operational.

9. Results: Messages

This chapter presents the results from the focus area of messaging in relation to the aim of establishing the need and value of such a function and the development of a design suggestion that incorporates these findings and provides high user acceptance. It includes the findings from the conducted research, the design specification, concept generated during the process, the evaluation results and the final design suggestion.

9.1 Research findings

The research for the messaging function had the most open-ended entry of all the focus areas. The research was to establish whether a messaging function was desirable to implement at all, but also evaluate which of several possible implementations should be pursued. The interviewees showcased a striking alignment in their views of a messaging function.

First, needs of a messaging function could be identified. The expressed needs were almost identical for all interviewees. The purpose of a messaging function would be to allow communication of critical information to all people present on the construction site. This could be forwarding of safety critical information from a daily supervisor meeting, information regarding deliveries of construction equipment or information regarding restricted access to areas for safety purposes (eg. operational zone for a crane). This information delivery is currently handled through notes which are placed throughout the site, mass briefings with megaphones or through word of mouth. These methods have several drawbacks. Collecting everyone for a mass briefing or placing notes across the site is time consuming. Placed notes are also easily missed and word of mouth is acknowledged to have poor spread (few people reached) and even worse reproduction of information (wrong or incomplete message forwarded). Furthermore, all current methods lack feedback behavior. The messenger can get the information out but not perceive how many have actually taken part of it.

Secondly, the option of implementing the possibility to accompany evacuation notifications with a message was rejected. Interviewees expressed how this could cause misunderstandings related to the urgency of an evacuation. One interviewee said that an evacuation notice should be absolute and not leave room for personal interpretation, which could be the case if the cause of the evacuation was stated through a message.

As a need for a messaging function had been established further insights regarding more detailed implementation was also collected, also with high alignment among interviewees. All interviewees specifically requested one-way communication. That comments, responses or reactions should not be supported. The reason given was that this could flood the flow with low priority comments and easily escalate far away from the high-priority safety related information that the interviewees requested. Furthermore, a need to select recipients of the message both individually and based on company was identified in order to deliver appropriate information to affected people. The ability to send images and PDF:s as well as scheduling the publication (eg. writing a message one week and publishing it the next when the information becomes relevant) was identified as important.

The feedback issues previously discussed prompted a need to implement a feedback mechanism that would inform the messager how many have seen the message. Interviewees expressed that it would be important to know both the total number of readers, but specifically the share of those currently on site who have read it. This constitutes a form of secondary situation awareness. The messenger knows that the information they are sending is important for creating situation awareness among the recipients. And since the state of operations is influenced by the situation awareness of all people on site, it becomes an important measurement for those responsible to know the reach of those messages. In other words, the messenger should be able to acquire situation awareness regarding how well they have been able to spread situation awareness among others.

The reason for acquiring these insights is both to understand how up to date the current team on site is and to have evidence of distribution of information for safety breaches.

9.2 Design specification

The insights from the research was concretized into a design specification consisting of requirements and guidelines. The whole design specification is available in appendix F and the most significant requirements and guidelines are presented in this section.

First, the need for a messaging function could be expressed as the requirement of allowing the messenger to communicate information to people working at the construction site. This was complemented by a guideline stating that the messaging function should save the messenger time to communicate information. Furthermore, it is required for the messenger to be allowed to filter who receives the message, both individually and by group such as by subcontractor companies. A requirement to allow scheduling of messages for later publication was also included.

Based on the findings that users value a purely high-priority massaging function with one-way communication, a requirement to not allow commenting and reactions was included. To provide a secondary situation awareness the design was also required to provide information regarding which receivers have seen the message and specifically which people on site have seen it.

9.3 Concept

With the design specification as a framework, a concept was developed for evaluation with users. It incorporated the messaging function on the home tab of the app. From here the user could access a page for creating the message, including selection of receivers, attachment of files and scheduling of publication. Furthermore, the possibility to pin messages for a set amount of time was incorporated to allow the information to stay in a prioritized position on screen during the full time the information would stay relevant. The concept also incorporated the possibility to see how many people have seen the message and a separate overlay for discerning the share of views based on if users are on site or not.

9.4 Evaluation and feedback

During evaluation, interviewees expressed that the concept as a whole was easy to understand. They appreciated the ability to filter out people who they wanted to send a message to, both based on individuals, since the users often don't want to contact everyone, and based on groups such as subcontractors. Furthermore they liked the possibility of being able to pin messages and attach files to the message. Consequently, the final design suggestion underwent small changes from the evaluated concept.

9.5 Design suggestion

The design suggestion for the messaging feature utilizes the home tab for showing and interacting with messages. With the messaging function together with the notifications from data, the home tab now becomes a place where critical information can be easily accessed immediately after entering the app. Placing messages here is in line with the focus on a safety critical character of messages sought by the users. Users with the permission to write messages can access the function through the plus button. Once a message has been written and published it is placed in the regular daily flow on the home tab. From here users can see who has read the message and the author can access the functionality for editing the message. The flow for the messaging function is showcased in figure 9.2.

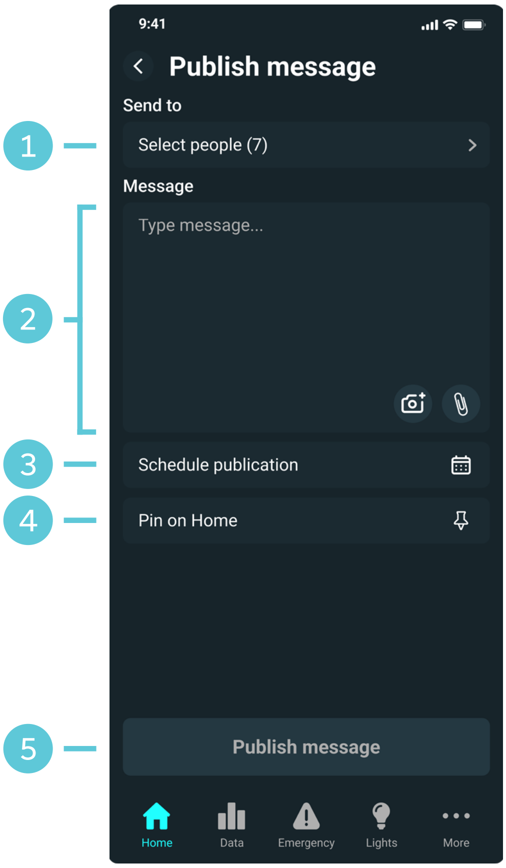

Figure 9.1. *Publication page.*

With the page in figure 9.1 the users publish their messages. On top of the page (1) the user selects who to send the message to in order to allow for more precise communication. This button opens an overlay which is presented in figure 9.3. Below (2) the user creates their message. Here the user can attach files and photos. Further down on the page there is a schedule button (3) and a pin button (4). These are used to schedule the publication of the message and to pin the message on the home tab for a set period of time to allow for control of how long the information stays in a prioritized view on the home tab. Lastly, the publish button is at the bottom of the page (5).

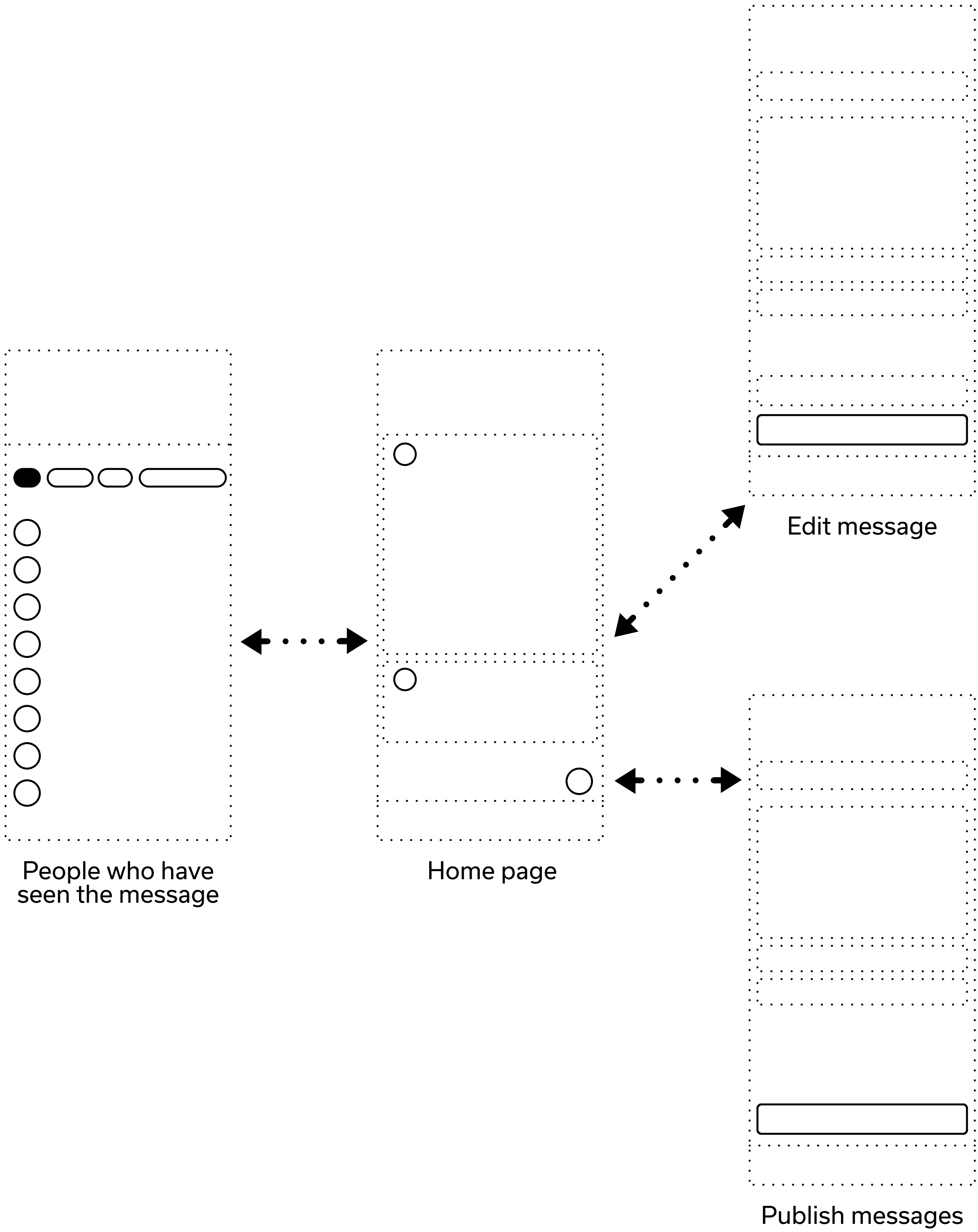

Figure 9.2. *User flow of messages.*

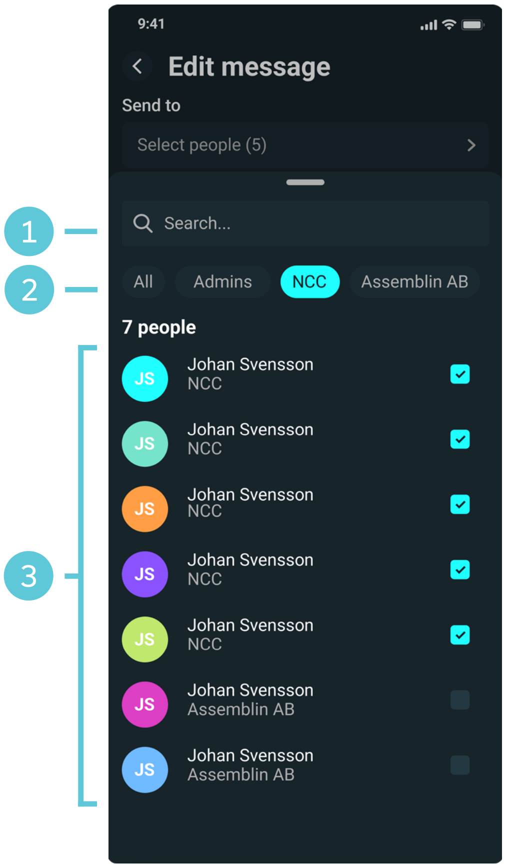

Figure 9.3. *Select people*.

The overlay where the user selects who to send their message to is presented in figure 9.3. The user can decide to search for people at the top of the overlay (1) if they want to send the message to a specific group of people. They can also filter out groups to send to, such as different subcontractors (2) which can increase the efficiency of use. The selection can also be made by selecting individuals one by one in the list (3).

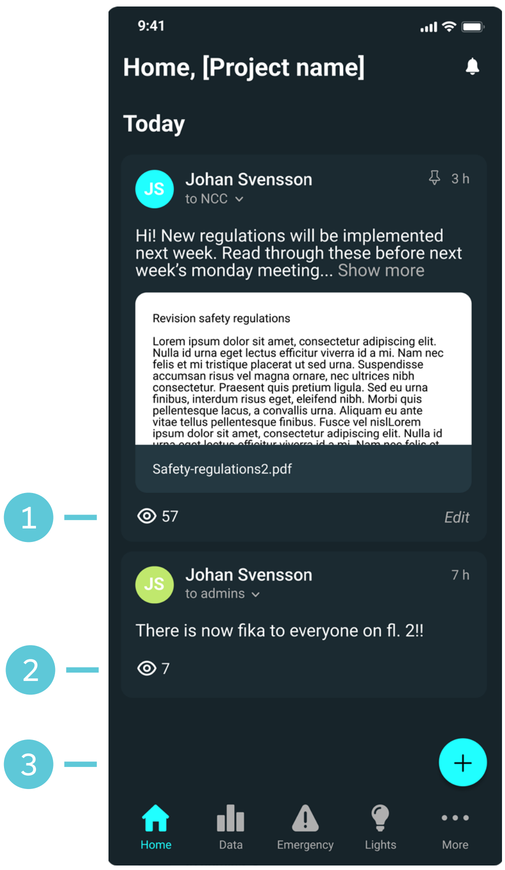

Figure 9.4. *Home page*.

When a message has been published it will be displayed on the home page as shown in figure 9.4. Together with the actual message, information on who the messenger is, time of publication, who the message has been sent to, and the number of people that have seen it is provided (2). The messenger can also access the edit button in the bottom right corner of the message card (1) if changes need to be made or if the user wants to delete the message. Clicking on the button that showcases how many people have seen the message opens an overlay which is shown in figure 9.5. To write a new message, the user can press the plus button (3) to access the page for writing a new message.

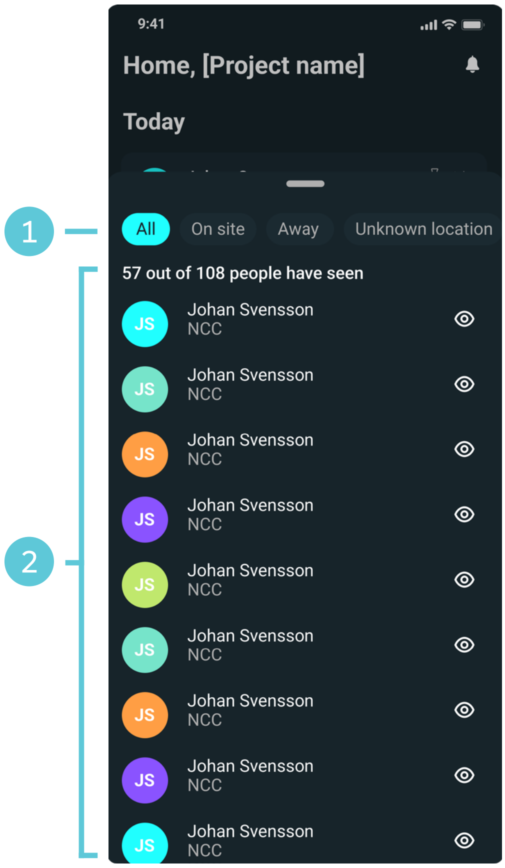

Figure 9.5. *Who have seen.*

In figure 9.5 the overlay of people who have seen the message is displayed. On top of the overlay there is a filtering option (1) where the user can filter recipients based on their location (eg. to see people on site who have seen the message). The selected filtering will then appear in a list below (2) with an eye icon for every user that has seen the message. The design suggestion incorporates GPS for identification of peoples location but a more accurate potential development for future implementation is the utilization of the electronic personnel ledger used at every construction site for determination of whether a user is on site or not.

9.6 Summary

The most notable findings from research includes that messaging constitutes a desired functionality and that it would be used for communication of important safety critical information. During evacuation however, messages should not be provided as it could cause misunderstandings. The most notable value associated with a messaging function would be increased resource efficiency in relation to spreading information and the possibility of receiving feedback regarding the spread of messages. The design suggestion incorporates messages in a feed on the home tab with the possibility to pin messages for a set amount of time. This implementation, together with the threshold and goal information, means that all important information for the current work day is collected on the first page that a user meets in the app. Furthermore, implementation of the possibility of seeing how many people have read the message based on their current location allows messengers to generate understanding of the level of knowledge transferral among the current team.

10. Discussion

This chapter covers discussion about particularly impactful decisions regarding methodology and design. Furthermore it highlights generally applicable findings and insights that can be utilized for future endeavors in the development of Brinja's app or user interface design for the construction industry in general. The discussion is divided into the areas of methodology used during the thesis work, the results in the form of design suggestions and lastly recommendations about future research and development.

10.1 Methodology

Overall the methodology used in this project has proven appropriate for acquiring insights about the work on construction sites, the use of the construction app and how to support tasks and processes through user interface design. The iterative application of research, evaluative methodology and development has resulted in step-wise improvements and adaptations that have been firmly anchored in the context of the construction site and the needs of its users. A selection of methodological approaches and decisions with the potential to have a particular impact on results will be discussed in this section.

10.1.1 The process

As presented in chapter 4, the project has consisted of one initial research phase of discovery and definition, and two iterative phases consisting of development and evaluation as well as refinement and verification. The project has been research heavy with a particular focus on empirical data collection consisting of interviews with 11 people, some on multiple occasions. In combination with this, thorough theoretical evaluations have been performed.

The utilization of two major iterations for concept development and refinement has been particularly useful due to two characteristics of the project. Firstly, the fact that many of the focus areas have consisted of completely novel functionality without any previous references. Secondly, the fact that empirical data from interviews have constituted a major source of insights regarding the development of designs. Under these conditions, it has proven beneficial to have a first development phase to develop reference designs which have been able to act as mediating objects for empirical data collection. The benefit of this approach has been evident in how considerably more insightful data regarding the novel focus areas was extracted during the evaluation interviews than during the initial research interviews. The major evaluation phase before further concept development has allowed collection of insights not only regarding the concepts but in many cases deeper and more nuanced insights regarding the users work and needs in general, than what the initial research phase was able to acquire.

For focus areas constituting developments of existing solutions, however, the initial discovery phase acted as important input for development. We especially believe that the combination of theoretical evaluation methods applied on the existing user interface design to identify usability issues and empirical data collection from users to map out the context of use and to generate understanding for the work has aided effective concept development. With a lack of previous experience from the construction industry, with its highly specific approaches and conditions concerning work methods and technology adoption, the utilization of initial interviews to establish a framework for understanding the work in construction, was also necessary in order to anchor solutions in the context where they are to be applied. We believe this has laid a good foundation for understanding the users and design issues which in turn has created good conditions for designing the user interfaces. The many iterations of the development and refinement phase has allowed for improvement upon the ideas and designs in relation to user needs and requirements. In conclusion, we think that the process has been fitting for finding out what the users need and want, to explore design solutions and to improve them in the context of working with a mobile user interface used at construction sites.

10.1.2 Selection of interviewees

The interviews were conducted with a broad set of different users. Their experience ranged from experts to no experience at all, covering the whole spectrum. The group of people also had different responsibilities and therefore different tasks at the sites, meaning different types of use cases were covered. The large variations in user profile covered by the interviews has allowed for data collection of the breadth of needs present, but the very large variations present also means that all views from construction have likely not been covered. However, during the course of this thesis work a large portion of the possible interviewees from Brinja's customer base have been interviewed, meaning that the coverage in relation to Brinja's product is high. Furthermore, during KJ analysis of later evaluation results no major new themes were identified, indicating that a level of saturation was achieved, at least in relation to the major areas of importance to the design.

In the case of the messaging function, only site managers who had expressed previous interest in such a function were included in the evaluation of the prototype. This was relevant for the evaluative purposes of the functionality of the prototype but the results are not necessarily representative for all potential users, which could consist of construction workers with a less positive attitude toward the functionality itself (lower perceived usefulness). However, the selection is representative for potential future customers of the messaging function.

The focus area of setting up new projects is mainly intended for a new customer segment that will buy devices over the counter. However, all people interviewed about this focus area were existing customers that had gotten projects started through the current procedure. These are not necessarily fully representative for the new customer segment, since they could have different priorities about what the product should deliver. It would have been beneficial to interview potential future users of the over the counter products. But with little currently known about this new segment and with its users not yet fully defined, no way to achieve this was found. Instead a lot of the insights came from Brinja's collected knowledge and theoretical evaluations of the current set up. Furthermore, the users who were interviewed have the same professional role and experience level as can reasonably be expected from the new customer segment. Therefore, deviations in terms of identified needs and priorities are likely not major. The interviewed users constituted the best approximation of users from the new customer segment that could be achieved.

10.1.3 Selection of prototype filtering

As Lim et al. (2008) remarks, the evaluative results of prototypes are impacted by the selection of filtering, i.e. what aspects are embodied in the prototype and what aspects are left out. For the evaluations in this project the way in which the different flows are connected in the large scale structure of the interface has been left out. Furthermore, as the data prototype was created as a vertical prototype with only one of several parallel flows available, the interactions between different parallel paths was not incorporated. This filtering decision was made on the basis of resource usage for prototyping in relation to the value of the information that could be attained. In relation to evaluation of how users access the different functions, it is worth mentioning that for all focus areas except data visualization, the shortcut plus button on the homepage acts as one way to access the function. This has been incorporated in several of the prototypes and shown to be easily interpreted by users, indicating that no major issues would arise regarding access to the different functions.

However, in the future one could explore how the focus areas' incorporation into the large scale interface impacts the usability and how a user moves freely and explores the house parts and floors in data.

Furthermore, an aspect which has not been included in the prototypes and thus filtered out of evaluation is how the current naming system can be transitioned to the new location management system. The evaluation has covered how the new naming system would work on the basis that it is implemented from the beginning of a project. This does not consider that current projects with a different naming system need to be transitioned. A possible solution if this presents any issues in some projects is that new naming is entered manually by Brinja to make sure it is appropriate for the new naming system.

10.1.4 Selection of prototyping tool and evaluation context

For the creation of evaluative prototypes, Figma has been used. The use of Figma has allowed for fast prototyping with a high enough level of interactivity to reach the filtering properties deemed relevant. Overall it has been highly effective as a tool for evaluation and has had the benefit of creating high fidelity visualizations for concept communication in the same workflow. However, the choice of using Figma for all evaluations as opposed to functional programmes has limited the possibilities for fully representative in context evaluation. Since figma does not support reacting to input such as real data, visualizations and responses in the prototype do not mirror how real world responses would look. For this reason, in context evaluation was considered to contribute with limited additional value as compared to evaluations in a laboratory environment and were thus not performed. Potentially some insights could have been lost as a result of this. The most notable example of how the real environment could have impacted the results is in the set up of new devices where the user would actually actively interact with the devices in the workflow. However, issues with this interaction would likely have been uncovered during evaluations with Brinja's expert user who has a highly developed mental model of the process and therefore an understanding of how the real world interaction would couple with the interface interactions. Despite this, effects as a result of the context have not been fully explored.

10.2 Results

The results of the project are constituted by, firstly, extensive research findings regarding the current use of Brinja's app, the workflow and processes present at construction sites and the needs of the app's users. Secondly, five design suggestions for a user interface design of five different focus areas have been presented. Evaluation and verification of the design suggestions have showcased a general high appreciation among users with indications of potential for high user acceptance and added value due to improvements in the support of users tasks and workflows. In this section the implications of certain design decisions will be discussed and generally applicable findings brought forward in relation to previous research.

10.2.1 Acceptance of upgrades

In the cases of new functions, extensive measures have been taken to assure a high level of acceptance among users. These are highlighted where applicable in the results chapter. In the cases of upgrades of existing functionality the mechanisms that affect acceptance are more complex. These will be discussed in this section.

A major change of an existing function is that of how data is visualized in the interface. It has undergone both the addition of a new level of tabs, substantial changes to how data is displayed and a number of additions of functions and information. As Strawderman and Huang (2012) points out, all design changes lead to short term drops in user performance. With the substantial changes of data visualizations, there is going to be an initial reduction in user performance and it is likely going to take some time for users to become accustomed to the new design and learn to navigate it efficiently. However, reading data constitutes a controlled task, i.e. it requires substantial knowledge processing and adaptations from use case to use case. According to Strawderman and Huang (2012) users recover relatively well from changes to controlled tasks as no previous behavior has been learnt. Thus, the changes are unlikely to have far reaching negative effects on user productivity over time. Furthermore, one must consider the tradeoff between the initial negative effects and the future positive effects. As the current design did not always correspond to optimal task performance and was expressed by users to be slow to navigate, the benefit of the redesign can be considered to outweigh the drawbacks in terms of initial loss of performance.

One aspect urging special attention is that of the guessability, i.e. the ease with which a first time user can guess how to use the interface, of the data visualizations on the current view. The evaluations of concept two highlighted issues regarding its guessability. Several measures were therefore taken to improve the guessability for the final design suggestion. Firstly, the different sensors are no longer differentiated only by a symbol but also through text. Secondly, the fact that the visualization concerns a span of current readings of different devices instead of a span of readings over time is highlighted through the tab name, current (just nu). Thirdly, the highest and lowest value of the final design suggestion is more prominently linked to the lines indicating devices in the bar chart. They are connected not only through proximity but also through an arrow from the value field to the line. Verification showed that these changes improved guessability but that users still had some uncertainty regarding how to read the data at first glance. However, given more time and freedom to explore the interface freely than what was allowed for during verification we believe that users will be able to learn to interpret all aspects of the visualization independently, as one user also pointed out during evaluation. Our opinion is that this visualization constitutes such a powerful tool when learnt and adapted into the workflow of users that it motivates the slightly higher initial threshold to learn it. However, if implemented, further analysis regarding guessability and learnability should be pursued. If deemed necessary a help page that introduces new users to the functionality could be implemented.

The other most notable change of an existing function is that of setting up a new device. In this case it is relevant to consider that the current access to functionality impacts how users adapt to it. Since end users have never set up devices themselves, they have not become accustomed to that task. However, they have been in contact with the result of the activity in the form of the name given to devices and how this is displayed. Therefore, for end users the focus area of setting up new devices constituted partly new functionality and partly a product upgrade. The part constituting a change for these users (the naming and display of naming) has been evaluated both in the flow of the actual set up procedure and in the display of locations in data. Here, the display of the device location was indicated to have high levels of acceptance.

For Brinja's expert users, however, the full set up procedure constitutes a change of existing functionality. For them, the set up procedure is also a part of the app which they have very frequent interaction with. Furthermore, for these users the set up is a relatively automated task. It is performed in a similar fashion each time and has to a large extent become a learnt behavior. According to Strawderman and Huang (2012), changes to such a task have the potential to have a lasting negative impact on performance, especially if the change constitutes the addition or removal of a step in the process. This task is therefore the most critical of the focus areas in terms of how a change impacts the users productivity. Therefore, feedback from Brinja's expert user has been thoroughly considered and accommodated. It should also be noted that the current design was expressed by the user to not be optimal in terms of workflow which actually hindered productivity. All of the issues highlighted by the user have been accommodated in the redesign and during evaluations the user expressed that the redesign better supported the workflow.

The set up procedure has undergone one major instance of commission (addition of a new step), namely that of the feedback page. However, evaluations did not indicate any negative impact as a result of this. Furthermore, this change constitutes an addition of a step in the actual set up flow but since the user previously had to go to another part of the interface to find the same feedback data it is not an addition in the overall workflow. Instead it can be considered a change of sequence in which the feedback step is included in the same flow as all other tasks related to setting up a new device.

10.2.2 Exchanging personal education with guiding UI

The new user segment of over the counter customers is not able to acquire the educational onboarding session with Brinja employees. As highlighted by Park and Park (2020), educational satisfaction is one of the main determinants of user acceptance of new construction IT. To counter the omission of onboarding in person, a guiding project start-up checklist has been included in the UI to provide the users with a way to acquire the same knowledge and experience with the app as a personal meeting with Brinja. This guidance constitutes a form of scaffolding.

As Janson et al. (2020) illustrates, scaffolding in technology-mediated learning processes can have a considerable impact on learning satisfaction. There are however uncertainties regarding how successful this exchange can be. Scaffolding does not permit the user to ask questions which could solve uncertainties in the learning content. This increases the requirements on the interface to be self-explanatory. However, scaffolding benefits from requiring the user themselves to explore and learn by doing. Another benefit in the context of Brinja's app is the fact that more users can become accustomed to the project start than what would be the case with an in person onboarding where only one person participates. This means that, as different people could be responsible for different aspects of the project start, all people responsible could have access to relevant guiding material.

10.2.3 Risks of automated decision support systems

For the focus area of data visualization, a decision support system was introduced as part of the design suggestion. As covered in 2.2.5, automated decision support systems can introduce automation bias among its users. The support system suggested consists of the user getting notified when next steps in the process can be initiated. This suggestion would be based on when a specific compressive strength has been reached, and therefore constitute a low level decision support in which a specific data state triggers the notification. Although the research shows that performance increases with decision support systems, users can become over reliant and fail to identify errors. However, we deem the risks related to this issue to be low for the design suggested. The reason is that the low-level decision support without extensive processing of data does not introduce errors other than those which are a result of measuring errors which would be present even without the added support. As research showed that users have highly developed mental models for interpreting and understanding the effects of data errors, it is likely that the same processing would take place for the new feature.

10.2.4 Generating situation awareness through distributed cognition

The introduction of new data visualizations and a messaging function has considerable implications for the generation of situation awareness. This is an important development in the context of the construction industry. The research has shown that in the construction industry, tasks and responsibilities are highly distributed, i.e. different users have highly specified responsibilities that overlap to a low extent. Furthermore, there is a low level of communication regarding tasks and responsibilities between users. This means that knowledge transfer of information which would benefit the situation awareness of several users is unlikely to happen through means of personal communication. Endsley and Jones (2004) express how individual task performance benefits from transfer of situation awareness attributes between individuals but that the same purpose can be achieved through universal access to the same information.

In this regard, material distribution of cognition can act to suppress deficits in social transferral of information, by instead providing the same material embodiment of the information to everyone. In this thesis work this is utilized in the fact the app can act as a material embodiment of information that is available to everyone. As long as the app shows the necessary data to generate situation awareness, the effects of having low levels of social distribution of cognition are mitigated. This is particularly evident for the messaging function, where a user would get the information considered important for their work at the time when it becomes relevant to them, when arriving at the site. Furthermore, new functionality for data, such as goals, enables all users to generate awareness of processes from the representations within the app. These mechanisms have the potential to become highly incorporated into the users' cognitive processing of states at the construction site and act to increase situation awareness through this material distribution of cognition.

10.2.5 Environmental, societal and ethical considerations

The design suggestions developed in this project have, beyond the implications in regards to usability, situation awareness and user acceptance, the potential to impact processes within construction with more far reaching effects. The developments of data visualization with goals and progress notifications, as shown in the design suggestions, will provide users with support in taking action to optimize processes in relation to environmental performance, e.g. energy usage for concrete heating. Although the immediate effects might have marginal impact, the size and total impact of the construction industry means that even minor changes, if applied at large scale, can have a big impact. Since the construction industry is responsible for a large portion of the total greenhouse gas emissions, an increased use of the Brinja app and an increased situation awareness of the status of construction sites has a potential to result in impactful decreases of greenhouse gas emissions. By increasing awareness of the progress of concrete hardening users will acquire the necessary preconditions for taking action to decrease energy consumption for heating. An increased awareness of the concrete hardening can further speed up construction progress by allowing for efficient resource planning and as a result lead to buildings getting constructed faster which is of a societal interest.

The developments also have impacts in relation to safety and work environment. One aspect is the developments of data visualization to support better situation awareness of processes and safety critical measurements. Through the development of visualization of measurements such as carbon monoxide, dust and noise, awareness regarding safety issues is increased and measures can be taken before anyone is harmed. The most notable change in regards to human safety is that of messages. The messaging function presents new opportunities to reach all personnel with safety critical information in efficient ways. Today, construction workers run the risk of not receiving all information. By increasing the availability of critical information the messaging function has potential to prevent accidents. Furthermore, the ability to receive feedback about how many persons that have seen the information enables users to take action if spread is low. Increased availability of easily accessible information for all workers, regardless of their professional role and position, also addresses issues in relation to information ethics and equal access to information of value to the individuals present in the construction industry. By giving workers increased control and oversight of their work environment, they acquire tools to impact the conditions and themselves contribute to increasing their own and their colleagues' safety.

In extension, the design developments proposed could result in more users and interest in the Brinja app. The introduction of features such as messaging and goals which would be of interest not only for supervisors and site managers but also for workers, could accelerate adoption among all people on the construction site. This has implications for the level of usage of features which are outside the scope of this project but that through increased use improves the construction site's safety and environmental performance. Examples include the light control which decreases energy usage and the evacuation system which has the potential to save lives in the case of an emergency.

A number of ethical issues must also be considered. One is the utilization of GPS data to determine whether users are on site or not. Although the intention is to increase the safety of people on site, it does constitute a privacy issue since it allows for a level of tracking of a user's location. To limit the invasion of privacy the functionality is suggested to only allow other users to see a binary state where users are presented as either on site or away and exact location is not disclosed. This binary information is already collected through the electronic personnel ledger required at every construction site and thus constitutes a limited addition to the invasion of users' privacy. Furthermore, users have the ability to disallow the app access to location data from GPS, which is a tradeoff between allowing users control of their privacy and achieving an effective tracking of the reach of messages. The reasoning is that a high enough share of users are likely to accept the usage of location data to generate usable estimates of the reach of messages while users concerned about GPS tracking will still be able to use the app and get critical information without giving away their location data.

There are also ethical considerations in relation to the design suggestion's implications in relation to safety and accountability. This is relevant specifically in the area of the decision support for process initiation. Since decision support can cause users to put more trust in the recommendation presented by the technology and less trust in their own intuition or judgment, it is important to consider the risks introduced by this potential redistribution of responsibility for conclusions and the accountability for faulty decisions. The effects of a potential faulty decision can be severe, e.g. the removal of support structures for not yet structurally sound concrete can cause collapses. However, since the low-level decision support does not process or alter data but is triggered by the same data currently used (and trusted) for decision making, the design suggestion proposed is unlikely to result in accidents that would not have happened without it (see 10.2.3). The perceived responsibility for decision making among users could however be impacted by the introduction of decision support. These effects would have to be further studied but it is likely that the users' education and mental models will prevent a perceived redistribution of responsibility from the user to the technology.

Furthermore, a high level of data transparency and oversight in the design suggestion allows users to trace goals and threshold breaches to the source datapoint. This is important since it means that the user is never required to put their trust in opaque and unverifiable algorithms but instead have the ability to scrutinize the source data behind the system's behavior. Since the user is accountable for their decisions it is an important ethical consideration that they also have full access to the information underlying the decisions. Through the graphs page the user can see the data values for each individual device over time and thus evaluate the seriousness and reliability of data and states that trigger goal or threshold notifications.

10.3 Recommendations and future developments

During the project a majority of considerations from research have been implemented in the design of user interface solutions and evaluated with users. However, due to methodological decisions and the scope of the project, additional potential for improvement that remains for future research has been uncovered. These will be discussed in this section.

10.3.1 In context evaluation

As design suggestions of the different focus areas are developed into functional parts of the app, evaluation of the performance for actual task compilation in context would be relevant. This is to ascertain that no unforeseen effects negatively impact how the interface design is incorporated in the workflow of the users. However, as extensive user studies regarding understanding of functionality and how to use the interface as such have been undertaken in this thesis work, we deem only limited verification to be necessary. This could incorporate short follow up interviews with users who have started to use the new functionality. Furthermore, as to understand how the redesigns positively impact the efficiency of processes on the construction site, follow ups after a time of use would be relevant.

10.3.2 Automation of processes

This thesis work has also identified an area where further research and development of the app could generate additional value for customers, namely automation. This thesis work proposes design suggestions of the user interface that lowers the need for users themselves to process large amounts of information through decision support. This develops the interface from requiring users themselves to analyze data for the next action to giving the users indications about what action to take. An additional step would be to not require the users to take action at all, but instead fully automate select processes. One such example would be concrete heating.

The goal from a user's perspective is that the concrete never reaches temperatures below 0 degrees centigrade and that the process finishes in time. By using the data collected to automate heating fans so that these requirements are met, users would not have to take action themselves. Furthermore, there are far reaching environmental benefits to be gained through such an implementation. By keeping heating consumption at a minimum while still achieving the required goals of the process, substantial energy savings can be achieved. The interface suggestions of this report helps guide users with taking appropriate actions to save energy, but reactions from humans will always be delayed. A human's reaction to turn off or on heating will result in slow responses in the system. An automated process could reduce these. Implementing such a system would require research into how heating equipment could be integrated into Brinja's system which is outside the scope of this thesis work.

10.3.3 Scalable data functionality

An effect of the design decisions regarding the menu system of the data tab is that the design is highly scalable. The tabs on the data page constitute a menu which can be scaled up if more alternatives would be identified in the future. This means that if future user research identifies additional functionality which could be relevant to implement these can be added as a new tab. The only consideration for such a change would be if the implementation affects large scale understanding and supports navigation without added confusion. Except for this, there are no constraints as to how the data functionality could be scaled. One example of a potential function that could be added is visualization of energy consumption from connected lights. As lighting is outside the scope of this project, this has not been included in the design suggestion but we see no limitations to such a development in the design suggested.

11. Conclusion

This chapter presents the conclusion of the thesis work and summarizes its results in relation to the aim.

In this thesis work, extensive user research consisting of interviews with a broad set of users in construction have been conducted. It has uncovered an industry with a low amount of convention and large variations in systems used between construction sites. Furthermore, work tasks are highly distributed between different professional roles and individuals, creating diverse needs regarding functionality in construction programmes and apps.

A data model for location description, that is possible to incorporate into the varying internal systems used at construction sites, is proposed. Furthermore, user interface designs optimized for task completion for users without prior experience of setting up devices or projects in Brinja's app have been developed. They have been shown to be easily learned and appropriate for efficient task completion.

The research has established a number of tasks for which data is used within construction and that processes and actions taken are highly affected by the data and the situation awareness it enables. Data visualization that showcases an overview of spreads of large amounts of data has been found appropriate for generating global situation awareness while combined with graphs that enable comparison of detailed information over time. Presenting select information and action indications early and saliently enables users to act on data for process initiation and safety.

Mass communication between construction workers has been found to be lacking, resulting in difficulties with sharing safety critical information and spreading situation awareness. Messaging with the ability to get feedback on the spread among users at the site has therefore been developed.

Evaluations of the concepts have indicated high levels of user acceptance and the potential to drastically improve the preconditions for generating situation awareness. Furthermore, the requirements from research have been fulfilled meaning that the designs are thoroughly anchored in the requirements and needs identified in the industry and from its individuals. This is also evident in evaluations where the design suggestions were shown to support the tasks of users in an efficient way. With these developments the aims of this thesis work have been fulfilled and future developments in the form of process automation have been proposed. The findings and solutions proposed can also be used as a knowledge framework for future endeavors in the digitization of the construction industry, specifically regarding the development of user interfaces.

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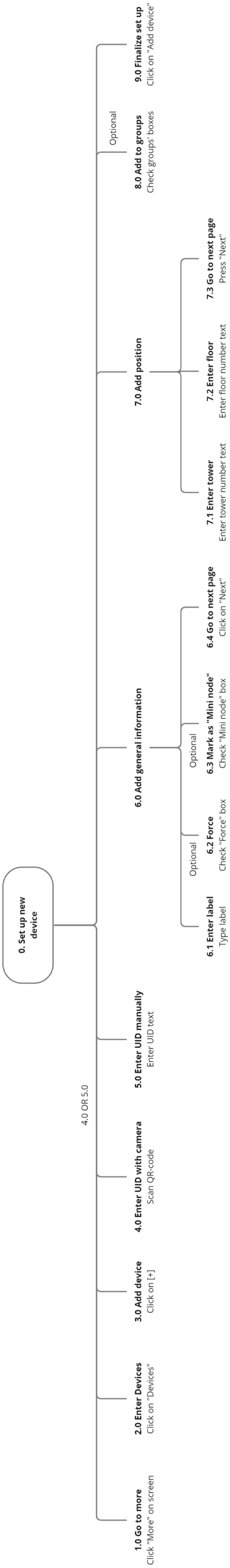
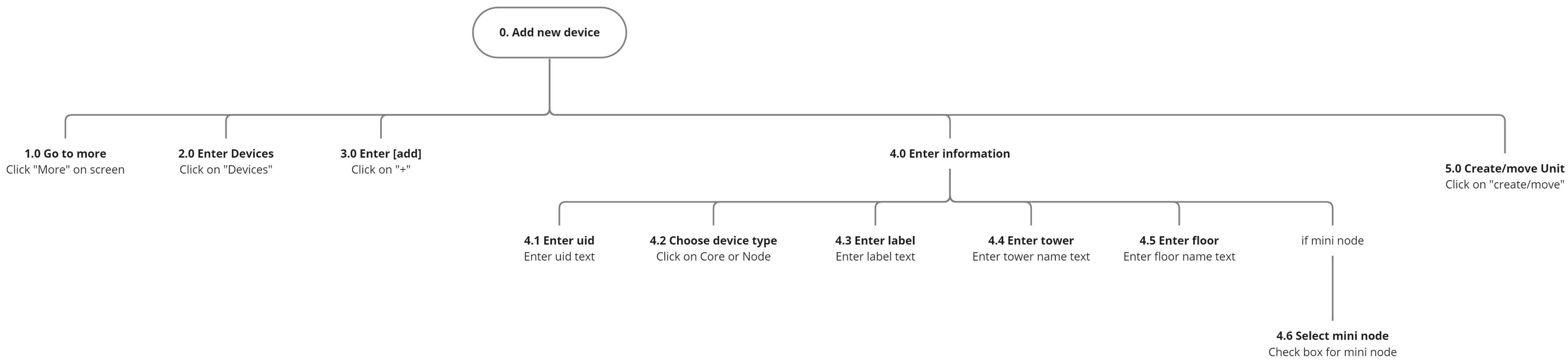
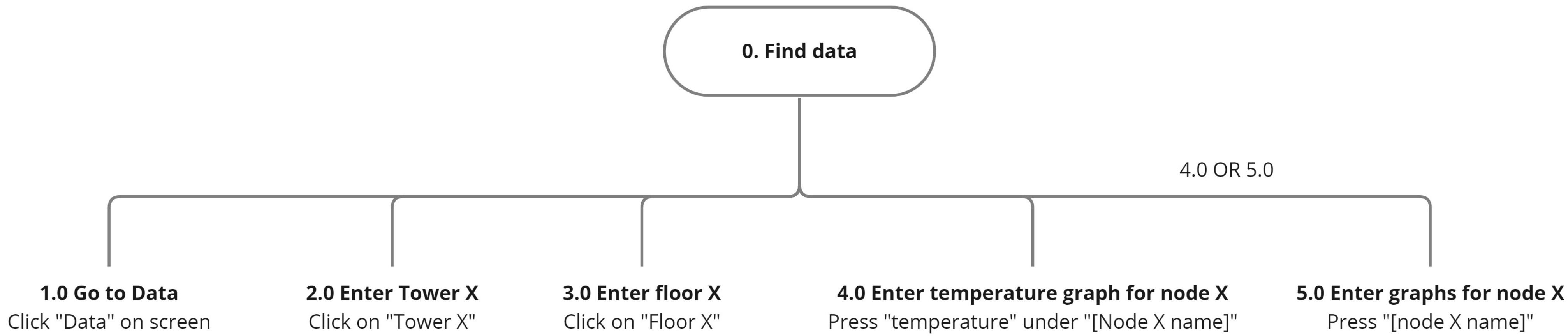
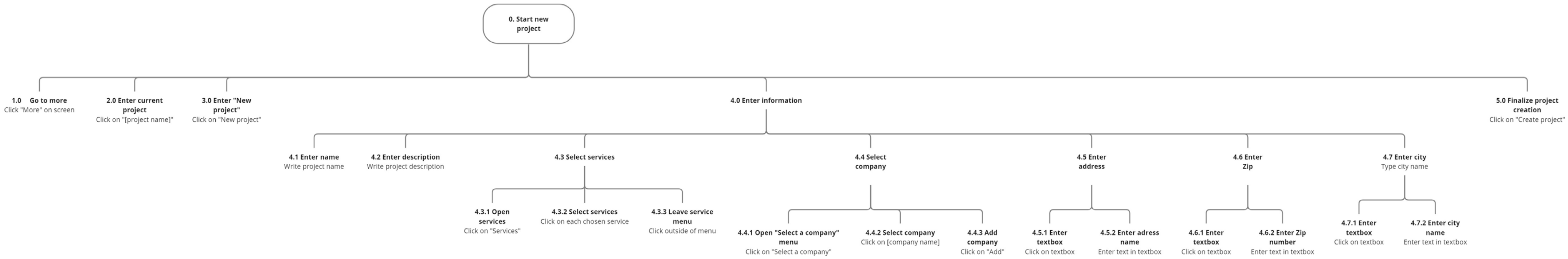
Appendix A - HTA




0. Add new device
1.0 Go to more
Click "More" on screen
2.0 Enter Devices
Click on "Devices"
3.0 Enter [add]
Click on "+"
4.0 Enter information
4.1 Enter uid
Enter uid text
4.2 Choose device type
Click on Core or Node
4.3 Enter label
Enter label text
4.4 Enter tower
Enter tower name text
4.5 Enter floor
Enter floor name text
if mini node
4.6 Select mini node
Check box for mini node
5.0 Create/move Unit
Click on "create/move"


0. Find data
4.0 OR 5.0
1.0 Go to Data
Click "Data" on screen
2.0 Enter Tower X
Click on "Tower X"
3.0 Enter floor X
Click on "Floor X"
4.0 Enter temperature graph for node X
Press "temperature" under "[Node X name]"
5.0 Enter graphs for node X
Press "[node X name]"


0. Start new project
1.0 Go to more
Click "More" on screen
2.0 Enter current project
Click on "[project name]"
3.0 Enter "New project"
Click on "New project"
4.0 Enter information
4.1 Enter name
Write project name
4.2 Enter description
Write project description
4.3 Select services
4.3.1 Open services
Click on "Services"
4.3.2 Select services
Click on each chosen service
4.3.3 Leave service menu
Click outside of menu
4.4 Select company
4.4.1 Open "Select a company" menu
Click on "Select a company"
4.4.2 Select company
Click on [company name]
4.4.3 Add company
Click on "Add"
4.5 Enter address
4.5.1 Enter textbox
Click on textbox
4.5.2 Enter adress name
Enter text in textbox
4.6 Enter Zip
4.6.1 Enter textbox
Click on textbox
4.6.2 Enter Zip number
Enter text in textbox
4.7 Enter city
Type city name
4.7.1 Enter textbox
Click on textbox
4.7.2 Enter city name
Enter text in textbox
5.0 Finalize project creation
Click on "Create project"

Appendix B - ECW & PUEA

ECW & PUEA - 4.0 Enter UID with camera First time user

ECW

Operation:	PS	Fail/Success Story	Usability Problem	PT	Notes
1. Will the user try to achieve the right goals of the operation?	4	Maybe not	They might not know what QR-code is or that they are visible on the units	U	When moving responsibility to scan units to the user they must get to know the difference between a core and node
2. Will the user be able to notice that the action of the operation is available?		Yes			
3. Will the user associate the action of the operation with the right goal of the operation?		Yes, camera opens up with frame			
4. Will the user be able to perform the correct action?		Yes			
5. Will the user get sufficient feedback to understand that the action has been performed and the goal has been achieved?		Yes, user is taken to the next step			

PUEA

- What can the user do wrongly in this operation?
- What happens if the user performs this operation at wrong time?

Error & Type	Error Cause	Prim. Consequence	Sec. Consequence	Detection	Prevention	Recovery	Protection
Wrong code scanned - A6	Slip - accidentally scan the wrong code	Wrong unit entered	5 - Innconvenient to rescan	4 -	Error message when scanning an already active unit	Yes, the user can go back and rescan	None

ECW & PUEA - 8.0 Add to groups First time user

ECW

Operation:	PS	Fail/Success Story	Usability Problem	PT	Notes
1. Will the user try to achieve the right goals of the operation?		Yes			The user cant create a new group in this menu (compare; spotify new playlist)
2. Will the user be able to notice that the action of the operation is available?		Yes			
3. Will the user associate the action of the operation with the right goal of the operation?		Yes			
4. Will the user be able to perform the correct action?		Yes			
5. Will the user get sufficient feedback to understand that the action has been performed and the goal has been achieved?		Yes			

PUEA

- What can the user do wrongly in this operation?
- What happens if the user performs this operation at wrong time?

Error & Type	Error Cause	Prim. Consequence	Sec. Consequence	Detection	Prevention	Recovery	Protection

ECW & PUEA - 5.1 Enter Label First time user

ECW

Operation:	PS	Fail/Success Story	Usability Problem	PT	Notes
1. Will the user try to achieve the right goals of the operation?	3	Maybe	Unclear if the user understand what label means	T/U	
2. Will the user be able to notice that the action of the operation is available?		Yes			
3. Will the user associate the action of the operation with the right goal of the operation?		Yes			
4. Will the user be able to perform the correct action?		Yes			
5. Will the user get sufficient feedback to understand that the action has been performed and the goal has been achieved?		Yes			

PUEA

- What can the user do wrongly in this operation?
- What happens if the user performs this operation at wrong time?

Error & Type	Error Cause	Prim. Consequence	Sec. Consequence	Detection	Prevention	Recovery	Protection
Enter a name which does not describe the unit well - A7	K- User does not understand the purpose of adding the text	Non-descriptive label filled out	5- Confusion and difficulty identifying devices later on	Never or when the user or other users sees label later on	Clearer information regarding purpose of the label	It is possible to alter labels on already set up devices	None

Appendix C - Heuristic evaluation 1

Data visualization

Visibility of system status

Positive

Neutral

In “data overview” and “floor selection” the sensor data has been indicated to be non-interactable through the same faded design used throughout the app, however the squares around each datapoint is similar to the squares used for intractable content in the app and there is a risk that users will interpret each datapoint as a functioning button.

Negative

The user might not know what data is displayed on the “data overview” page (eg. mean for all sensors in tower, average mean over time, one sensor etc)

Match between system and the real world

Positive

The sensor symbols clearly represent what they are in the real world.

The symbol of a node on the select sensor stage clearly aids in understanding what the selections relate to

Neutral

A way to increase connection to real world and make navigation easier would be through representative symbols for the towers (eg tower, apartment building, terraced house)

Negative

User control and freedom

Positive

Back arrow is taking the user to the previous page

The user can choose between showing all sensor data for a node or selecting one datapoint

Neutral

Negative

Consistency and standards

Positive

Same symbols as in the rest of the app.

Neutral

Negative

There is inconsistency between the two first levels and the third level regarding a rectangle around the selection and being able to choose separate sensors. This could lead to confusion.

The text size for towers and floors are bigger than sub-headers in other parts of the interface (eg. home tab). The use of smaller text for sub-headers clarifies order of priority.

Sensors and units are not displayed in the same way on the graph page

Error prevention

Positive

Neutral

Negative

Recognition rather than recall

Positive
All towers and floors are displayed and clickable.
When the user has selected tower, the selected tower is displayed as header
Neutral
Negative
On some phones the header on the third level is cut off, requiring the user to remember where they have entered. Could be remedied by removing “tower” from the tower name.

Flexibility and efficiency of use
Positive
Personalization of what data is being presented in the graphs.
Neutral
Negative
The tree-structure of the menu requires many clicks to enter and move between parts of the structure

Aesthetic and minimalist design
Positive
Neutral
Negative
A lot of information is presented to the user at the same time
No division or categorisation of alternatives makes the first page slow to comprehend and get an overview of
The “tower” text on each alternative adds little information while adding visual complexity

Help users recognize, diagnose, and recover from errors
Positive
Neutral
Negative

Help and documentation
Positive
Neutral
Negative

Start new project
Visibility of system status
Positive
The “create” button is darkened until all information has been filled out. When done, the button becomes lightened.
Parentheses with the number of services and sensors chosen is a good way to indicate that a selection has been made
Neutral
Negative
The page header “Project” does not clearly explain what the page is for. “New project” or “create new project” might be more helpful.

Match between system and the real world
Positive
Neutral
Negative

Possibility for misunderstandings regarding some of the explanations. Eg Name (Project name), description (project description), Address (construction site address)

User control and freedom
Positive
Clear exit sign
Easy to go back and edit/change/redo
Everything is on the same page
If wrong information is entered the user can change it afterwards.
Neutral
The user must fill in every textbox to create project
Negative

Consistency and standards
Positive
Neutral
(Do symbols follow ISO standards?)
Negative
To start a new project the (super) user selects "new project" which is a field button below available projects. To join an existing project the user presses "+" in the top right corner. These two similar functions are inconsistent on the same wireframe, leading to uncertainty.
The "+" button to join an existing project is inconsistent with other "+" buttons in the interface which are placed as an overlay in the bottom right corner. (eg. under devices)
Some sensors use the same symbol (eg. relative humidity, absolute humidity, absolute humidity difference & Temperature, maturity)
When selecting company the user can add a new company by pressing "add" in the top right corner. This is inconsistent with other ways of adding in the app where this is often indicated with a "+".

Error prevention
Positive
A project can not be created with sufficient information.
Neutral
Misspellings are not corrected.
By having a list with companies a user could select the wrong one.
Negative

Recognition rather than recall
Positive
The use of symbols in front of names for sensors and services utilises recognition to make identification faster (Although currently risk for mix-up when using the same symbols for several measures)
Neutral
Negative

Flexibility and efficiency of use
Positive
Company selection through both search and list
Neutral
Negative

Aesthetic and minimalist design

Positive
Neutral
Is “description” necessary at this stage?
Negative

Help users recognize, diagnose, and recover from errors
Positive
Neutral
Negative
No error message or explanation why a project can not be created.
No error message if a field is incorrectly filled (eg not a zip code with 5 numbers)

Help and documentation
Positive
Neutral
Negative

Install new device
Visibility of system status
Positive
Progress bar clearly displays the progress of the set-up.
Checkboxes are clear
Neutral
Negative

Match between system and the real world
Positive
Clear symbol of the unit scanned.
Neutral
If the code on the physical devices are referenced as “UID” the step of scanning or manually adding UID corresponds to real world language but a novice user is likely not familiar with the wording which could potentially result in confusion.
Negative
A novice user might have trouble understanding that a qr-code is to be scanned at the “Scan UID” step. Can potentially be solved with a small symbol of a qr-code.

User control and freedom
Positive
Neutral
Is it possible for the user to go back to the previous step?
Do the user want to automatically to the next step after scanning the qr-code
Negative

Consistency and standards
Positive
Neutral
Is tower - floor standard name giving?
Negative
Lacking consistency with headers and progress bar steps (Scan UID vs. UID and Groups vs. device groups)

Error prevention
Positive

Neutral
Negative
The user might accidentally leave the set-up through the back arrow button, while they try to go to the previous step (feedback message “Do you really want to leave?” might be relevant)
If the idea is that users are supposed to go back to the previous step by pressing the dots on the progress bar, it would be beneficial to make them bigger to indicate intractability (eg like thresholds)

Recognition rather than recall
Positive
Nice symbol of the scanned device
List of existing device groups
Good feedback on which project the device is added to
Neutral
Negative

Flexibility and efficiency of use
Positive
Enter UID manually is constantly available which allows the user two separate ways of adding a unit
Neutral
Negative
The user should be able to add new groups in “device groups”.
The many steps required to add a unit makes the process slower. It is unclear to us what the advantage of separating general info and position is. Also the last step device groups could potentially be included in a more streamlined add process with only one page for adding information. This would make the process more consistent with the process of adding a new project in todays interface. Is there a reasoning behind making this process in many steps?

Aesthetic and minimalist design
Positive
The picture of the unit and the text below it is clearly indicated to be non interactable by not having a rounded rectangular field like interactable elements.
Neutral
Remove “Mini node” for all users
Remove “Force” for the customer users
Can the progress bar be removed if there are only two steps?
Is it meaningful to present a picture, project name and UID?
Negative
By having both a page header and a text on the progress bar duplicate information is provided in the interface (could potentially make the current (selected) dot and text on the progress bar bigger and remove page header, however might add overall inconsistency)

Help users recognize, diagnose, and recover from errors
Positive
Neutral
Negative
The user might scan the wrong qr-code/insert wrong information. It is therefore important that the user can go back and fix the mistake.

Help and documentation
It's best if the system doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their tasks.
Positive
Neutral
In the add new device flow additional help could possibly be beneficial for novice users. The "?" symbol with additional help could provide this (eg regarding where the QR-code is located on a device)
The current "?" might be missed by a user. Moving it down to the UID rubric or camera box could improve relationships with what the help is about but could also make consistency within the interface as a whole worse.
Negative

Appendix D - Research questions

Generella

Vilken roll har du på arbetsplatsen?
Vilka arbetssysslor innefattar den rollen?
Hur vill ni använda appen? Vilka typer av processer ser du att Brinjas app kan underlätta?
Hur länge har ni använt Brinjas app?

Datavisualisering

Hur använder du datavisualisering (datafliken) i dagsläget?
Hur ofta tittar du på värdena och diagrammen? Tittar du på vyn med flera diagram eller en och en?
I vilket syfte går du idag in i datafliken?
Få överblick, få information om specifik sensor, se utveckling över tid eller just nu?
Vilka aspekter är viktiga för dig när du använder datafliken?
Tid, att det är lätt, att avläsning blir korrekt.
Skiljer det sig i olika användarscenarier. Tex om du går in för att kolla på byggarbetsplatsen eller om du går in och vill hämta ut diagram vid ett senare tillfälle?
Hur påverkas processer på byggarbetsplatsen av avläsning av information i appen?
Startas nya processer triggat av data, är dataavläsningen en säkerhetsåtgärd innan en process påbörjas eller påverkar det på något annat sätt.
Baserar du beslut på byggarbetsplatsen på information under datafliken?
Hur påverkas din förståelse av en byggarbetsplats av information under data?
Delar du den här datan med kollegor eller andra personer?
Kommunicerar du den här data till andra?
Vill du kunna sortera i vilken ordning olika husdelar/diagram visas?

Skapa nytt projekt

Vill ni kunna starta nya projekt själva?
Vad hade du tyckt om att denna uppgift hade flyttats till er
Varför tycker du som du gör? Effektivitet, smidighet, frihet
Hur svårt tror du att det är att starta ett nytt projekt?
Om ni skulle få i uppgift att utföra den här uppgiften, att starta upp era egna projekt, vad skulle vara viktigast?
Att det är lätt, går snabbt, att du är säker på att du gjort rätt etc
Hade du uppskattat att kunna ladda ner appen och testa den (navigera runt och se vilka funktioner den har) innan du gör en beställning hos Brinja?

Platsbeskrivning för enheter

Vad tycker du om det nuvarande systemet för platsbeskrivning för enheter? (dvs husdel, våning)
Använder ni ett liknande system för namngivning överlag på byggarbetsplatsen eller skiljer sig Brinjas app på något sätt?
Vilken typ av platsbeskrivningsinformation är viktig för dig?
Hur använder ni enheternas label idag?
Om ni ska titta på en enhets plats tittar ni på labeln eller husnummer och våningsnummer?
Om du fick drömma fritt, hur hade du velat att enheters platser beskrevs i appen?

Meddelande

Finns det ett behov av att kunna skicka meddelanden till andra användare i Brinjas app?

Hur hade du velat att meddelandefunktionen fungerade?
Vilka funktioner
Gruppmeddelanden
I vilka situationer eller scenarion hade du velat ha en medlande funktion?
Varför?
Har du någon gång startat en evakuering i appen?
Tror du att du skulle vilja kunna skicka meddelanden i en sådan situation?
Tex anledning till evakuering
Fritext eller förslag på meddelande?

Installation av enheter
Är det en hjälp eller ett hinder för er att installationen av nya enheter utförs av Brinja och inte er?
Har du erfarenhet av att själv placera ut enheter på bygget?
Om du skulle placera ut enheter själv, vet du var och hur enheterna skulle placeras på anläggningen?
Vill ni utföra installationen av enheter själva? (dvs att enheterna kommer till er utan att vara inlagda i appen och redo att sättas upp)
Vad hade du tyckt om att denna uppgift hade flyttats till er?
Varför tycker du som du gör?
Effektivitet
Smidighet
Hur svårt tror du att det är att installera en enhet?
Om ni själva skulle utföra den här uppgiften, och inte Brinja, vad skulle vara viktigt för er?
Tidsåtgången, att det är lätt, att installationen blir korrekt

Appendix E - Expert user research questions

Hur går installationen till idag, steg för steg? Görs momenten i olika ordning eller är det alltid samma?

Så som det ser ut idag, är det samma person som sätter upp alla enheter i ett projekt eller kan det vara olika personer? I så fall hur sker kommunikationen mellan dessa personer?

Vad är viktigt att tänka på när enheter placeras ut på platsen?

Hur ska enheter placeras för att fungera som dom ska? Vilka krav ställer enheterna på placeringen?

Placeras alla noder likadant, eller spelar det någon roll vilka typer av sensorer som används på dem?

Tar ni fram en bild för hur enheterna ska placeras ut innan ni börjar? I så fall, används den bilden när ni placerar ut enheterna?

Är ledare från byggprojektet med när ni placerar ut enheter, och vem är det som bestämmer den exakta placering i så fall?

Händer det att enheter behöver flyttas i appen? Tex om väggar byggs upp efter ett tag.

Appendix F - Design specification

PX - Interviewee no. X
SA-X - Situation awareness principle no. X

Location description/assigning

Requirement	**Source/reason**
Users must be able to assign locations within the app without knowledge of the app's internal naming structure	Internal communication
The solution should be scalable to different project sizes	
It should be consistent with the rest of the Brinja app	Consistency
Allow substitution of units (maintain location while substitute unit)	Internal communication
Guideline	
The location description hierarchy should follow: hus, husdel, våning, våningsdel	(SIS, 2016)
The user should be able to map the location description to the real world location	(SIS, 2016)
Brinja employees should be less dependent on own mapping notes to understand locations	P5
All common ways of location description should be possible to use in the app	Allow for external compatibility
When assigning, users should not have to remember the name of already added locations (husdel and våning)	Reduce memory load, reduce duplicates of names
The user should be able to add a new husdel and våning when assigning location	Prioritization of functionality
Device location description should not contain duplicate information (e.g. label that contains husdel and våning)	Consideration of user resources, explicitness, P5
Visualization of the description system should follow users' mental models	P9
The location structure should minimize unnecessary parts of information	P9, P7

Set up new device

Requirement	Source/reason
Users must be able to set up new devices in the app	Internal communication
Users must be able to move/relabel existing devices in the app	P10
The user should be able to select if previously gathered data stays or moves when moving the corresponding device	P10
A novice user must understand what is to be scanned	Heuristic evaluation & ECW & PUEA
The information to be entered in the app should correspond to the information on the device.	Consistency
A user must understand how a device should be placed for satisfactory sensor function	Internal communication
A novice user must understand how to set up a new device in the app without external information	Heuristic evaluation
The user should be able to go back to the previous step in the process	Heuristic evaluation, User control
The user should be notified when they are about to leave the process with unsaved changes	Heuristic evaluation, User control, feedback, Error prevention and recovery
Users must get feedback when a non-functional QR-code is scanned	P5
Users must get feedback when an already set up device is scanned	P5
Information on where and how the device should be set up, should be provided to the user	P5
The user must get feedback in the app that the device has been successfully registered	Feedback
The set up procedure should be adapted to what type of device is being set up	
The locations already entered in a project should be visible and selectable when defining position for a new device	P10
Guideline	
The purpose of all information entries should be clear to the user	Heuristic evaluation
Similar operations should be distinguishable (e.g. go back and exit)	Heuristic evaluation, Error prevention and recovery
Brinja work hours spent on setting up devices should be reduced	Internal communication
Brinja employee travel for setting up devices should be reduced	Environmental sustainability

The design should not contain unnecessary features for the user	Heuristic evaluation, visual clarity, consid-eration of user re-sources, prioritization of functionality and information
The user should be able to add the device to groups	Heuristic evaluation, Prioritization of func-tionality,
Number of unnecessary steps should be minimized	Consideration of user resources
Voluntary steps should minimize use of user resources (visu-al space, needed actions)	Heuristic evaluation, consideration of user resources, visual clarity
The user should get an immediate data reading from the device as feedback that it functions properly	P5, P9
The design should not contain unnecessary visual elements	Heuristic evaluation, P8
The design should be consistent with the rest of the Brinja app	Consistency

Data visualization

Requirement	Source/reason
Safety critical and/or urgent data-points must be visible without entering a menu structure	Prioritization of functionality and information
The design should provide visualizations of data over time through line graphs	P3
The design should display thresholds in graphs	P1, P2
Visualization of threshold breach or warning should be visually salient (stand out and be easily identifiable among other data)	P1, P2, (SA-1,2,5)
Data filtering should be available on the data export page	P7
Allow to display a reference value (from outside) on the page where data is read	P9
The user should get notified when a threshold is surpassed	P9, P3
The user should be able to filter specific units to show data from	(SA-1)
A user's filtering of which sensors data is displayed should remain the selection for the next time the user enters the data page	P7
A legend clarifying which graph corresponds to which device should be possible to access in graphs	
The user should be able to switch between appropriate graph timeframes with one (1) click	P9
For users with concrete sensors a merged 28 days diagram showing all concrete sensors with the same starting time should be accessible	P3
Overview of tower sensor data including deviating data points (outliers) should be accessible on the first data page	P9, (SA-4), P3
Notify the user when deviating data (threshold breached, threshold close to breach, outliers) occur with visually salient cues	P9
Notify the user when next steps in processes on the construction site can be initiated	P3
Notify the user when progresses fall behind of schedule	P3
Threshold levels should be visualized in the diagrams	P3
Estimated time to process completion should be provided on the first page in the data section	Prioritization of functionality and information
The system's suggestion for process initiation should be phrased as supporting information rather than commands	Automation bias
Guideline	

The design should be consistent with the rest of the Brinja app	Consistency
The design should provide good usability for data overview	(SA-4)
The design should provide good usability for specific data look-up	(SA-1)
The design should provide good usability of exportation of data subsets	
Time to reach desired diagram should be minimized	Consideration of user resources
Perceived clarity of information should be maximized	Visual clarity
Time until comprehension of safety critical data-point should be minimized	Situation awareness, P8
Elements that are not interactable should not look interactable	Heuristic evaluation, Visual clarity
It should be clear what symbols represents	Visual clarity
Time to find a specific location (husdel or våning) should be minimized	Heuristic evaluation, explicitness
The order of menu alternatives should correspond to the users' mental model	Mental models
Similar functions should have similar usage	Consistency
Minimize the necessary steps to reach the desired information/function from wherever the user is	Consideration of user resources
Do not present too much information to the user at the same time	Heuristic evaluation, Consideration of user resources
Sorting should be based on location rather than devices	Internal communication
Provide information on when the next phase of the process can be initiated directly (without further interpretation of eg. graphs)	(SA-1,2), P3, P4
Provide fastly accessible overview of data values reached for tower and floor	(SA-1,2), P3, P4
Breached or warning threshold should be easily coded to location of breach	
The interface should assist the user with projecting future status of system	(SA-3), P3, P4
The user should be able to view data development over time	(SA-1), P3, P4
Anomalies in sensor data should be easily and fastly identified without having to search for it	(SA-5), P1, P2,
The filtering option should be easy to comprehend (eg. follow the users' metal models)	P8
It should be easy to navigate between different pages.	P8
The filter function should be easily accessible	P9

The lines in the graph should be differentiable	P9
The design should support minimization of resource usage (fuel, electricity, money) by displaying when usage is superfluous	P3
Information for users which do not require other data for task completion should be easily identifiable early on the data page	P3
Support planning of processes and resource allocations through projected estimates of process progresses	P3
The design should support comprehension of large amounts of data	Visual clarity
The design should provide data for global situation awareness early on the data page and data for goal based situation awareness after filtering	(SA-4), P3, P9

Set up new project

Requirement	Source/reason
Users must be able to set up new project in the app	Internal communication
A user must understand how to set up a new project in the app without external information	Heuristic evaluation
The user should be able to go back to the previous step in the process	Heuristic evaluation, User control
The user should be notified when they are about to leave the process with unsaved changes	Heuristic evaluation, User control, feedback, Error prevention and recovery
It should be consistent with the rest of the Brinja app	Consistency
The project set up should contain entry of project name, company and adress	
Guideline	
The purpose of all information entry should be clear to the user	Heuristic evaluation
The header should clearly express what is being performed on the page	Heuristic evaluation, Visual clarity
Brinja work hours spent on setting up new projects should be reduced	Internal communication
Provide users with a positive first experience of the app	Internal communication
Enable users to start a project and navigate the app without previous contact with Brinja employees	Internal communication
The design should clearly express what information should be entered in each entry point (e.g. textbox)	Heuristic evaluation
Use the “+”-button in a consistent way throughout the interface	Heuristic evaluation, Consistency
The creation of a project should not create duplicate names for the same company in Brinjas database	Heuristic evaluation
The user should not be able to decipher which construction companies are Brinja customers	Heuristic evaluation
Avoid unnecessary steps in the process	Heuristic evaluation, Consideration of user resources
User should be notified when and if an information entry has been incorrectly filled out	Heuristic evaluation, Feedback
Voluntary steps should minimize use of user resources (visual space, needed actions)	Heuristic evaluation, consideration of user resources, visual clarity
The project set up should guide the user to set up of project, billing, new device and new user.	

Messaging

Requirement	Source/reason
Allow the messenger to communicate information to people working at the construction site	Internal communication, P10, P11
Allow the messenger to filter out who is being communicated to	Internal communication, P10, P11
Allow the messenger to filter out who is being messaged based on company	Internal communication, P10, P11
Provide information to the messenger on who have read the information	Internal communication, P10, P11
Provide automatic translations	Internal communication
Only send notifications to people who are at the construction site	P6, P11
Allow messenger to pin messages for a set amount of time	P6, P10
Allow messenger to schedule when message will be sent	P6, P10, P11
Allow messenger to see the share of people currently on site who have seen the message	P6, P10
If the receiver is not present at site when pinned message is sent, they should get notified when arriving at the site	P6, P11
The messenger should be able to edit messages	P11
The messenger should be able to delete messages sent	
Admins should be able to give people permission to post messages	P10
A commenting function should not be provided	P6, P10, P11
Messenger should be able to specify if a new notification should be sent when updating a message	P11
The receiver should be able to access the original message after it has been translated	Internal communication
Allow the messenger to attach files in the announcement	Internal communication, P11
The messaging function should not be accessible during an evacuation	P6, P10, P11
Guideline	
The message should be easily accessible in the app for both the receiver and messenger	Internal communication, P6, P10, P11
The messenger should be able to acquire a sense of how many have perceived the information	P6, P10
Messages should function as evidence that information has been provided to receivers	P6, P10, P11
The messaging function should save the messenger time to communicate information	Internal communication, P10

Appendix G - Evaluation questions

Betongsensorer & övriga sensorer

(Förklara att det bara är en prototyp så att inte allt fungerar.)

Lämna över och be honom att försöka utföra något som han normalt sett ofta skulle göra i appen.

[Testa version 1] - [Specifik uppgift] - [Utforska fritt]

Vad är ditt spontana intryck av konceptet?

Vad tycker du är bra/dåligt med konceptet?

Hur tänker du att konceptet skulle passa in i ditt arbete och stötta dina arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

Lämna över och be honom att försöka utföra samma uppgift som på koncept ett.

[Testa version 2] - [Specifik uppgift] - [Utforska fritt]

Vad är ditt spontana intryck av konceptet?

Vad tycker du är bra/dåligt med konceptet?

Hur tänker du att konceptet skulle passa in i ditt arbete och stötta dina arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

————————

Vilket av koncepten tycker du mest om, varför?

Om du jämför koncepten med dagens app, är de bättre/sämre, på vilket sätt, varför?

Stöds ditt arbete bättre med något av koncepten (jämfört med det andra eller dagens app), vad är det som gör att arbetet stöds bättre?

Ev. fråga om automatisk kontroll av värmefläktar baserat på en tidsplan man sätter

Set up new device first
Förklara bakgrund till varför det här konceptet ska testas. Förklara att det bara är en prototyp så att inte allt fungerar.

Första enhet: Vi skulle vilja att du installerar den här enheten på Radhus 1, våning 2, Badrum. Samt att lägg till den i gruppen badrum.

[Lägg till enhet]

Vad är ditt spontana intryck av konceptet?

Hade du uppskattat att du skulle kunna utföra den här uppgiften själv?

Vad tycker du är bra/dåligt med konceptet?

Hur tänker du att konceptet skulle passa in i ditt arbete med dina nuvarande arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

Känner du dig trygg i att du lyckades med att slutföra uppgiften?

Set up new device second
Förklara bakgrund till varför det här konceptet ska testas. Förklara att det bara är en prototyp så att inte allt fungerar.

Finns befintliga enheter: Vi skulle vilja att du installerar den här enheten på Trapphus A, våning 8, Badrum 1. Samt att lägg till den i gruppen Badrum.

[Lägg till enhet]

Vad är ditt spontana intryck av konceptet?

Hade du uppskattat att du skulle kunna utföra den här uppgiften själv?

Vad tycker du är bra/dåligt med konceptet?

Hur tänker du att konceptet skulle passa in i ditt arbete med dina nuvarande arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

Känner du dig trygg i att du lyckades med att slutföra uppgiften?

Messages
Förklara bakgrund
Hur ser ditt behov av att kunna skicka meddelanden i appen ut?
Hur kommunicerar ni information på arbetsplatsen idag?
Om du har använt meddelanden tidigare, vad använde du dom till?
Är det någon särskild funktionalitet du efterfrågar?
En- eller tvåvägskommunikation?
Reaktioner som att gilla?
Kommentera?
Se hur många och vilka som sett meddelandet?
Enkäter?
Bifoga filer?
Hur integreras en meddelandefunktion med dina övriga arbetsuppgifter. Kan du

spendera mindre tid på andra saker med hjälp av meddelanden, får du bättre överblick av processer på bygget osv?
Vilket värde hade detta genererat för er
Vad hade du varit beredd att betala för det här
Hur hade ni velat bli debiterade för detta, per månad, projekt, personer i projektet?
Vilka features är det som hade gjort att ni hade varit beredda att betala det här?
Komma till alla som är på arbetsplatsen

Set up new project
Tänk dig att du själv skulle vilja starta ett nytt projekt för en annan byggarbetsplats i appen, hur tänker du att du hade gjort då?

[Testa konceptet]

Vad är ditt spontana intryck av konceptet?

Hade du uppskattat att du skulle kunna utföra den här uppgiften själv?

Vad tycker du är bra/dåligt med konceptet?

Hur tänker du att konceptet skulle passa in i ditt arbete med dina nuvarande arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

Känner du dig trygg i att du lyckades med att slutföra uppgiften?

Vad av de sakerna som finns på landningssidan (projektuppstart) hade du gått in och gjort själv (fylla i faktureringsinformation, lägga till en användare och lägga till enhet). Om inte du, vem hade kunnat göra det istället?

Vad är ditt spontana intryck av konceptet?

Vad tycker du är bra/dåligt med konceptet? Är det något du tycker är otydligt?

Hur tänker du att konceptet skulle passa in i ditt arbete och stötta dina arbetsuppgifter?

Hur väl tycker du att målet/uppgiften kunde genomföras?

Appendix H - Heuristic evaluation

Set up new Device
Visibility of system status
Positive
UID is displayed
Device type is clearly displayed
“Lägg till enhet”-title is clear
Progress is displayed at position overlay page
New positions are clearly differentiated with number of devices and “lägg till ny enhet” text
Check boxes are clear if active or not
Clear that device is added to project (green color, check mark, text)
Loading screen clearly indicates that something is loading
Status bars clearly displays status of device
Clear feedback what device is added
White text in textboxes when added
Neutral
Negative

Match between system and the real world
Positive
Image represents the real world device
Position levels follows standards and user mental models
Position order follows conventions (alphabetically, bottom-up)
Neutral
Negative
Positions do not follow a mental model if the mental model order is other than alphabetically or bottom-up.

User control and freedom
Positive
Allows user to back and rescan device, while saving typed information
Allows users to go back in position over-lay
User can escape position overlay through clicking outside overlay
Neutral
Negative
Going back in position overlay is not displayed as clickable (down-prioritized because of aesthetic and minimalist design

Consistency and standards
Positive
Position hierarchy follow industry standards
Neutral
While following internal consistency within the app with its naming of positions, it does not always follow real world naming
Negative
Name of position levels does not necessarily follow all project standards

Error prevention
Positive
Warning if user is about to change the position of already added device
Neutral

Negative

Recognition rather than recall
Positive
UID is displayed on main page
Positions and groups is shown and accessible on main page when added
Already added position information are shown in the progress field in the position overlay
Images are guiding what is to be added in the position overlay
Order of added floors in position overlay shows which was the last addition
When users are about to change the position of a device they are reminded of the current position of the device
When changing position current position is highlighted and written
Neutral
Negative

Flexibility and efficiency of use
Positive
Adding groups is optional
Skipping steps when adding or changing position is possible
User can leave set up when status is loading
Text is already put in when adding a second device or changing posistion
Neutral
Negative
User most click on position and then click on “våningsdel” when only changing “våningsdel”

Aesthetic and minimalist design
Positive
Neutral
Information (image of device and device text) that is not necessary is displayed
Negative

Help users recognize, diagnose, and recover from errors
Positive
Error messages are clearly expressed
Help is provided for users not having any device
Neutral
Negative
Recovery is an impossibility when having added a device (trade of between non-interactable page) (can be changed under “devices”

Help and documentation
Positive
Help is accessible trough-out the set up
Images are displayed of that is to be typed in the position overlay
Neutral
Negative

Data visualization
Visibility of system status
Positive
Header identifies where you are

Sub-tabs are visible all the time so the user does not get lost in the structure
Selections clearly stand out through coloring
Green to indicate that status is normal and red to indicate a breach
Highest and lowest value defines the full status of the system
Goals clearly show their progress status through bars
Under current there is a header explaining which house part the user has entered
Neutral
Negative

Match between system and the real world
Positive
Phrasing follows users mental models
Neutral
Are the symbols representing the real world
Negative

User control and freedom
Positive
There are few actions which take the user to a position which needs to be reversed and in all those cases there are clear back options
No actions are permanent
Neutral
The graph buttons on the current tab takes the user to a new tab, however this is clearly indicated in the tab menu and can be reversed just by clicking the old tab
Negative

Consistency and standards
Positive
The design follows standards
Neutral
Negative

Error prevention
Positive
No error are permanent
Neutral
Negative

Recognition rather than recall
Positive
Under current there is a header explaining which house part the user has entered
Units directly at value reading doesn’t require the user to remember the unit from another place in the interface
Legend when holding at graphs makes it clear which graphs are shown instead of requiring the user to remember their filtering
Filtered sensors are visible so the user don’t have to remember their selections
The time interval being visible all the time shows the current graph scale instead of having to remember a filtering selection
Neutral
Negative

Flexibility and efficiency of use
Positive

Flexible filtering
The option of showing a graph of any level of the current view makes the usage flexible in terms of navigating between views
The dedicated goals page means that users that only need this information doesn't have to navigate other data
The overall structure of the interface with many different needs accommodate makes it highly flexible and adaptable to every user
Extensive filtering is available in export
Thresholds can be disabled in graphs
Neutral
Negative
No filtering of devices and sensors is not available on current
No averages are available

Aesthetic and minimalist design
Positive
Only necessary information included
Neutral
Negative

Help users recognize, diagnose, and recover from errors
Positive
Neutral
Negative

Help and documentation
Positive
Neutral
Negative

Set up new project
Visibility of system status
Positive
It is clearly expressed that the user is not logged in
It is clearly expressed what the user needs to do to get started
It is expressed that the code is sent
Indicates that an account has been created
Continuous feedback that the user is in a demo project
Feedback on the progress of the project set up and what is left to do
Chosen language is visible
Neutral
Negative

Match between system and the real world
Positive
User's language throughout the design
Neutral
Negative

User control and freedom
Positive
User can go back (and log out)
Neutral

Negative

Consistency and standards
Positive
Follows standards
Neutral
Negative

Error prevention
Positive
Neutral
Negative

Recognition rather than recall
Positive
Inserted phone number is visible
Steps of what to do is visible
After a performed step of the set up process it is visible on how to perform is again
User can select from a list of companies instead of writing the name themselves
Neutral
Negative

Flexibility and efficiency of use
Positive
User can press the fields under project start up as a shortcut to get to that set up without having so search in menues
Neutral
Negative

Aesthetic and minimalist design
Positive
No unnecessary steps included
Neutral
Negative

Help users recognize, diagnose, and recover from errors
Positive
User can resend code for account creation
Neutral
Negative

Help and documentation
Positive
Neutral
Negative

Messages
Visibility of system status
Positive
Number of people chosen is visible on edit page
White text when people chosen
Attached PDF:s visible on sending page
Scheduled publication date is visible

Pin duration is visible
Information on people who have seen the message is accessible
There is a differentiation between publishing and updating messages

Neutral
Negative
No preview of images
No appropriate formulation when people chosen

Match between system and the real world
Positive
Symbols (camera, paper clip, calendar and pin) are added on buttons
Neutral
Negative

User control and freedom
Positive
User can go back
User can delete messages
User can edit messages
Neutral
Negative

Consistency and standards
Positive
The "continue button" is at the bottom of the page
Neutral
Negative
Inconsistent use of multiple choice and single choice in user (recipient) selection

Error prevention
Positive
Extra step to delete a message
Neutral
Negative

Recognition rather than recall
Positive
Name of the file is visible
Neutral
Negative

Flexibility and efficiency of use
Positive
People selection based on company and other groups is accessible
Neutral
Negative

Aesthetic and minimalist design
Positive
People who receives the message is hidden under a drop down text
Extra long texts are shortened and accessible through a drop down function
Neutral

Negative

Help users recognize, diagnose, and recover from errors
Positive
Neutral
Negative

Help and documentation
Positive
Neutral
Negative

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