

Flow: an RE & UX analysis on a baggage handling SCADA system

UX change for a better workplace at the airport

Bachelor's thesis in Computer science and engineering

Aron Lund, Carl Toreborg, Casper Hansen, Hanna Forsling

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Cover: A screenshot of the updated system

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Abstract

The thesis presents a redesign of a Supervisory Control and Data Acquisition (SCADA) interface used for baggage handling at a Swedish airport company, with the aim of improving usability and system efficiency. It was found that the current system meets most of the users' needs but some adaptation was needed for a better user experience. The previous developers have used patterns for no particular reason other than that they should. Among the methods used to evaluate the UX, interviews were found to be the most effective and should therefore be used in future evaluations.

Applying user experience (UX) and requirements engineering (RE) together, a prototype was created using Figma and a set of functional and non-functional requirements (FRs and NFRs) was formulated as an additive to existing requirements. Data on the functionality as well as user feedback was collected using a static UX analysis, a user experience questionnaire (UEQ), participant observations, and contextual inquiry as well as phenomenological interviews. Seven users answered the questionnaire, and seven users were observed and interviewed in total. A qualitative data analysis method was performed to categorise data into themes, called thematic analysis, to identify user pain points and key areas to improve. Coding and conclusions drawn from the data were validated through peer reviews. To ensure that the proposed designs and requirements were ethically sound, they were reviewed against the Association for Computing Machinery (ACM) code of ethics. To ensure relevance, validation interviews were conducted with seven users. Following the feedback gained from this, the proposed design and requirements were revised and adjusted accordingly.

The project was based on an insight into usability issues in the current system experienced by baggage handling employees. The study aimed to evaluate the current system and suggest design improvements that aim to improve both operator satisfaction and system efficiency.



Sammandrag

Den här rapporten presenterar en ny design på ett Supervisory Control and Data Acquisition System (SCADA) gränssnitt, med avsikten att förbättra användarvänligheten och systemets effektivitet. Det nuvarande systemet fyller de flesta av användarnas behov men lite förändring behövdes för en bättre användarupplevelse. Utvecklarna av systemet har använt sig av designmönster men dessa har inte tagits fram tillsammans med de anställda på flygplatsen. Bland metoderna som användes visade sig intervjuer vara den mest effektiva och bör därmed användas för framtida utvärderingar.

Genom att tillämpa user experience (UX) och requirements engineering (RE) så skapades en prototyp i Figma och en uppsättning functional- och non-functional requirements (FRs och NFRs) formulerades som ett förslag på tillägg till nuvarande dokumentation. Datan samlades in via en statistisk UX-analys, en user experience questionnaire (UEQ), deltagande observationer samt kontextuella och fenomenologiska intervjuer. Sju användare besvarade enkäten och totalt sju användare observerades och intervjuades. Den insamlade kvalitativa datan analyserades med hjälp av tematisk analys, en metod för att kategorisera data i teman, för att identifiera användarbehov och förbättringsområden. Kodning och slutsatser granskades genom peer review. För att säkerställa etisk efterlevnad granskades förslagen mot Association for Computing Machinerys (ACM) etiska riktlinjer. Relevansen verifierades genom valideringsintervjuer med sju användare, och utifrån återkopplingen justerades både designförslag och krav. Projektet baserades på insikter om bristande användbarhet i det befintliga systemet, som upplevts av personal inom bagagehantering. Studien syftade till att utvärdera systemet och föreslå förbättringar som kan bidra till ökad tillfredsställelse bland operatörer och ökad effektivitet.

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1

Introduction

Airports today use many different systems for transferring luggage from the drop-off point to the destination of the passenger. The airport in Sweden studied in this report uses a SCADA (Supervisory control and data acquisition) system from a separate logistics company to monitor and control the various machines in which bags pass through at the airport. Running this machine are several baggage handling technicians who use a computer system to monitor the otherwise automatic flow. This system however, has its flaws.

The idea for this project was found while one of the students was employed by the airport. While working with the SCADA system on a weekly basis and talking to colleagues about its issues from a user's perspective, the idea of an evaluation of the software design and user interactions arose. Hohm et al. argues that industrial emphasis on safety critical user experience (UX) design needs further development, especially when it comes to the methodologies of evaluation [1]. This was also identified to be the case during initial meetings with the airport where no real user evaluation or communication had taken place for recent updates of the system.

This project aims to encourage the emphasis on user experience, as well as to improve the situation at the airport by using requirements engineering (RE) and UX design, as workplace satisfaction is shown to have correlation with the perceived usability of systems at these places [2].

1.1 Purpose

The purpose of this project is to aid the technicians who operate this specific SCADA system from a user's point of view, to create a better workplace environment for the users of this system both now and in the future.

By thoroughly mapping the operators' experiences using the system this study aims to describe the current UX and bring forth potential improvements of the user interface (UI). The final product is the academic paper documenting the process, as well as a deep UX analysis. A Figma prototype and a list of suggestions for re-designing the system will be brought forward to the airport operations company, which they may use in contact with the developers of the system. The aim is also for them to use the process when making changes in the future or if another vendor is chosen to provide the service and software.

This paper aims to answer the following questions:

- What are the needs and wants of the end users of the SCADA system?
- How can the company evaluate the user experience and elicit requirements in

- the future?
- Are there any UX patterns implemented in the current system and can these be improved?

1.2 Scope

The SCADA system in question has several views and parts which are linked with other systems. The SCADA system is intricately integrated with similar so-called Industrial Control Systems (ICSs) to successfully perform the entire operation. Some of the other systems look similar, while others look like different systems entirely. The scope of the project is limited to the overall view of specifically the baggage handling physical system, with exception of some parts of the system in regards to airport security, networking, and flight scheduling.

The scope includes a closer look at

- User navigation in the SCADA overview system
- Error/event messages
- Operative baggage handling functions such as resetting, starting and stopping conveyor belts
- Layout, colours, symbols and overall feel for the user when using the SCADA system

The scope does not include manual encoding stations or the baggage planning view (VIBES), focusing only on the airport's general baggage handling SCADA view.

Since security is a high priority at the airport, it is also included in the goals of the project. Yet, only as far as user faults are measured. This is achieved both by looking closer at user errors, as well as increasing awareness of the system and its requirements, which has been shown to increase security overall [3]. Under no circumstances will there be an evaluation of the security measures that the airport follows to eliminate threats and ensure a safe airport, as well as safe flights. In order to keep this as transparent to the company as possible, a Non Disclosure Agreement (NDA) was signed by all students to ensure safety for passengers, staff et al. and to be able to publish the work after the project is done.

Because of the above mentioned security, only workers at the facility were asked to evaluate the user experience. This division consists of around 19 people who are eligible for the study. The demographics for these workers are mainly men over 40 with a high computer proficiency.

The SCADA system for this project is a technological overview of a physical system for baggage handling. The scope of this project is not to evaluate the physical system but to evaluate how well the software system meets its requirements, if the requirements are functional as well as if it displays the physical system in a logical, sufficient, and user-friendly manner.

The scope does not include evaluating the current requirements in the system. The new requirements should only be seen as an addition to the existing documentation.

2

Theoretical background

The theory of this paper centres around both the system itself, as well as the theory behind UX and what constitutes good practice.

2.1 SCADA

A Supervisory Control and Data Acquisition (SCADA) system is always a subsystem of an Industrial Control System (ICS) and acts as a hub for data collection and control. The objective of a SCADA system is to centralize geographically separated components such as Programmable Logic Controllers (PLCs) or Remote Terminal Units (RTUs), collect data from these, issue commands remotely, monitor and control electrical distribution, and to relay the information to the operator. This provides the operator with control of the entire system from a centralised point, often a control room. A SCADA system is programmed to monitor specific components, accepted parameter ranges, as well as countermeasures for parameters going out of range [4].

ICSs exist as combinations of several systems, to achieve an industrial goal, such as transportation of a product. Other systems that a SCADA system may cooperate with are the previously mentioned PLCs, as well as distributed control systems (DCS). These systems may be either fully automatic or have Human Machine Interfaces (HMI) for operator control. They may operate in either an **open-loop**, where the output is controlled by approved settings, **closed-loop**, where the output controls the input to keep in line with the set objective, or in **manual mode** where humans control the system[4].

Today, industrial control systems and SCADA systems are widely used and are crucial to many industries and infrastructures, such as traffic control. SCADA systems are Cyber Physical systems. A cyber physical system is a system which intertwines both physical and software components to achieve a specific goal. Numerous industrial control systems have replaced previous physical control systems to enhance cost-performance. This evolution of IT into the industry's physical systems raises the connectivity and critical value of the physical systems, yet it also comes with a need to improve adaptability, safety, privacy, security, resiliency, and environmental impact while preserving a long life-cycle. To improve these points, SCADA systems are generally built with notable redundancy and designed to be fault-tolerant[4].

2.2 Requirements engineering

Zave defines requirements engineering (RE) as:

"Requirements engineering is the branch of software engineering concerned with the real-world goals for, functions of, and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behaviour, and to their evolution over time and across software families." [5, p.315].

Nuseibeh and Easterbrook [6] unpack this definition, suggesting that: First, "real-world goals" represent the "why" and "what" of a system. Second, "precise specifications" are a basis for requirements analysis, requirements validation, defining requirements, and requirements verification. And finally, "evolution over time and across software families" means that requirements can and need to change over time, and that they can be reused across different systems.

2.2.1 Requirement

A requirement is defined as follows:

"A statement that identifies a product or process' operational, functional, or design characteristic or constraints, which is unambiguous, testable or measurable, and necessary for product or process acceptability (by consumers or internal quality assurance guidelines)." [7, p.8].

According to Dick et al. [8] requirements are the foundation for every software project. It is a necessity to understand what stakeholders need from the system and what qualities the system must have in order to satisfy those needs. A stakeholder being "An individual, group of people, organisation, or other entity that has direct or indirect interest (or stake) in the system." Furthermore, half of the top eight most common project failure factors are directly related to requirements, the biggest factor being incomplete requirements. With the biggest problems regarding requirements being that they may be "poorly organized, poorly expressed, weakly related to stakeholders, changing too rapidly, or unnecessary; unrealistic expectations" [8]. A few of the problems can be directly linked to the formal definition of a requirement provided above [7]. Poorly expressed and poorly organised are directly opposite to unambiguous, as is unnecessary and necessary, of course. Problems regarding requirements and the lack of attention to requirements can be addressed at a low cost. Furthermore, requirements should be written in such a way that everyone can understand them and to avoid jargon and technical language. That is, even those with no technical background should be able to understand and make sense of every requirement [8].

2.2.2 Functional and non-functional requirements

To be able to facilitate a more structured and clear analysis, requirements can be divided into functional requirements (FR) and non-functional requirements (NFR). FRs capture what the system has to do, or is required to do, in terms of functions, services, or tasks. NFRs capture how well the system has to or is required to perform these functions in terms of quality [9]. FRs aid in the development life cycle by outlining business goals, and having a well-defined and extensive list of requirements contributes to creating a design that is both thorough and consistent [10]. NFRs play a key role in limiting the costs of a software project by limiting design choices and detecting design errors in the early stages of development [9].

In this report there are twelve FRs and nine NFRs, which have been elicited from interviews, observations, and surveys, that are suggested that the company adds to the current documentation of requirements.

2.3 UX analysis

According to Tidwell et al. the most important part of designing an interface is to understand its users and their needs. To analyse what the overall goal of the system is, break it down into subgoals and tasks, as well as keeping in mind what skills users possess, the language they use, and their attitudes [11, p.1, 26]. This can be further divided into four categories to understand users and to design an interface that they will be satisfied with:

- Context - Figuring out and understanding the audience
- Goals - What do users need or want to achieve using the system?
- Research - To further understand the context and goals
- Patterns - Understand behaviours and cognition related to the interface and its design [11, p.1-2, 26]

2.3.1 Context

When users use the system, it can be seen as a conversation between them and the system via its interface. When comparing this to a human-to-human conversation, it is important to note that there is an exchange of information and feedback going back and forth, as well as requests or commands, processing, and reception. An interaction between a user and a system should not be as spontaneous as a human-to-human conversation. Instead, there is a need for loops of feedback and for the system to be responsive and understandable. When designing or evaluating a software interface, it is important to note what users expect to see and what their intentions and motives for using the system are.

Depending on the software goals and different kinds of user groups, it is important to note the level of freedom that they crave from a specific interface. This can also be informed by their level of proficiency in similar systems. It is a fine line, if there is too little freedom users will feel stuck, if there is too much, they will instead feel paralysed, not knowing what to do. To set the correct amount of freedom and explorability, it is important to understand the users skill level, how willing they are to learn the program, and how much effort they are willing to spend. For example,

code developing environments are for intermediate-to-expert users, whereas online store pages are for occasional users. Most applications fall somewhere in between occasional usage and expert usage, such as social media sites and email clients[11, p.2-5].

Understanding the kinds of users the SCADA system has is a central theme of the project and will be used to inform design decisions.

2.3.2 Goals

The tools that users use has a purpose, whether it is to be entertained for the moment, perform an action, or monitor an object. To have a clear view of the purpose of the software it is important to ask users why they want or need the system. By asking what they want and need, it is possible to set an appropriate list of goals and subgoals, resulting in the ability to not only solve the correct problem, but also solve it in a correct way. Asking why, setting goals, and designing a system for a non-specific or "faceless" user seems deceitfully easy. Unless the user is properly specified and in mind, the design may not reflect the user's reality when later using the system. Therefore, context is crucial when setting goals[11, p.6-8].

Since this project builds on existing software, requirements, and work routine, these will work as informants for current user goals, as will the users themselves.

2.3.3 Design Research

To properly set the context and goals for the specific system and its interface, research is critical. There are several similarities between design research and market research, but there is one important difference; the reason for the research. Design research is done to better understand users and how they may use the interface to reach an intended goal, whereas marketing research focuses on understanding customers who buy a specific product.

To properly conduct design research, these are the learning goals:

- What goals do the users have for using the system?
- What specific tasks do the users need or want in order to pursue their goals?
- What language and specific words do the users use to define what they are doing?
- What skill level do the users have using similar systems?
- What are the users attitude towards the system that is designed and how can different design choices influence their attitude?

It is important to take time and effort to understand who the users are. A proper investigation is expensive in time and economic cost, but can lead to long-term satisfaction and a more proper design, which solves the correct problem in a correct way. To study users there are several methods such as direct observation, case studies, surveys, and creating personas [11, p.8-11].

2.3.4 Cognitive and Behavioural Patterns

In any UX study it is important to be mindful of the cognitive and behavioural patterns of the participants during observations and interviews. Since RE and UX

design are both interdisciplinary fields, it is important to factor in the following patterns to ensure that the study has the users' needs and wants in mind.

UX and Interface design combines knowledge of technology, design, cognition, and behavioural patterns. Psychology is essential to design a proper system interface, and some behavioural patterns are especially important to recognise [11, p.11-26].

The patterns explained below are used in the re-design as well as in the construction of the evaluation exploring the experiences of users.

A key for a user to have a positive experience of the whole system is **safe exploration**. In a well-designed interface, a user should perceive that it is easy to explore unfamiliar environments and try something that they have not done before. It is important to have a clear view of the system status, a clear correlation with the real world, and enough, but not too much, user freedom and control. This is to ensure a feeling of safety and curiosity for users [11, p.11-26].

Embedded in human behaviour and the human brain is the need for **instant gratification**. It is crucial for a user to be able to see the effects of their interactions with a system [12]. Users will feel more in control and secure if they receive a response from the interface that informs them that a task is completed, successful, or done. If a user has a task, it should be easy and quick to complete it and see the results. Long waiting times, commercials, and long sets of instructions are examples of discouraging walls that a user may need to pass in order to complete a task. Instead, to create a pleasant experience, it is important to understand user needs, have a clear entry point, and provide value or results, without asking too much of users [11, p.11-26].

A general user of a system tends to not read every single line of text or to understand the entire system fully. Commonly, users will, perhaps without a visible methodology, try parts of the system in order to solve their task. Using their instincts for the interface may lead to them succeeding, or not. **Satisficing** is a combination of the word satisfying and sufficing, and explains the phenomenon of "that it is good enough" [13]. To have this in mind for a designer or researcher means to consider how to give users proper instinctive direction, making markers and descriptions quick to read, and building the system interface layout in a communicationally meaningful way. It also means that it should be easy to navigate the system, that it should not be too cognitively complicated, and not have too much visual complexity. The behaviour of **satisficing** also means that users, after using the system for a while, may gain unusual habits. Breaking old habits is hard and may not seem worth it to users when making a design change [11, p.11-26].

When performing a task, a user may change their mind and want or need to perform another task. To **change in midstream** is a common behaviour and an opportunity within the interface to be able to switch or change tasks is essential for a designer to provide. Common design patterns which provide this are, for example, **modal panels** and **wizards**. Users may need or want to change midstream for no apparent reason, and this should be sufficiently provided within an interface, for the user experience to be positive. It is important to be able to easily start a project, cancel, (auto)save, re-enter, continue, stop, clear, and complete it. To support this, it is also possible to work with e.g. **many workspaces** side by side [11, p.11-26].

In a more creative process, users do not always have a specific order in which they complete subtasks or subprojects. To support this, it is important to build Builder-style interfaces with **incremental construction** in mind. A creation process has different steps for different users and may be individual [11, p.11-26]. This cognitive pattern is important to recognise and comes with a higher need for freedom within the system. This is supported by Mihaly Csikszentmihalyi and his theory on **flow**, a state where the user is so fully engaged in a task that they lose track of time and is positively entranced [14].

Another common behaviour is **habituation** which explains the phenomenon of actions becoming instinctive due to the human ability of pattern recognition. If a task has been successfully executed in a specific manner before, similar tasks and behaviours should yield similar results. For example, the computer keys a, s, d, and w are commonly used in computer games to move the main character. Should a designer change that to other letters, users would have a negative experience due to not naturally understanding the system. Changing the system so that it is opposed to instinctive behaviour could cause users to make errors. Habituation is based on consistency and can be used to improve efficiency and experience [11, p.11-26].

Closely related to habituation, when a user uses an interface they use **spatial memory**. That is, remembering how to do a task, e.g., by remembering where the button is placed, instead of reading the button text. For example, to close a window in an operating system (OS) users that use a Windows OS or Linux OS remember that the close button is placed in the top right corner, whereas MAC OS users remember that the close button is at the top left corner. If it would be placed somewhere else, users would have a negative experience while navigating through the system. For a designer or researcher it is therefore useful to look at where people are used to having certain navigations, buttons, and settings, as well as where it is practical for users to themselves be able to arrange objects. This is called **User-arranged areas** and an example is **movable panels** [11, p.11-26].

Many systems have functions or tasks that are necessary to perform repetitively or very often. For users to have a positive experience, these actions should be easy and fast to perform, with a minimal amount of keystrokes or clicks. This can be done using **macros** or having a layout which supports common objectives. To understand which actions need to be streamlined, it is important to understand the user, perhaps through observation, seeing what they use often and what they repeat. These tasks should not be tiresome, slow, or prone to errors [11, p.11-26].

Users also prefer different hardware for optimal navigation. Some do not like, or are physically unable, to use a mouse for an extended period of time, and some do not like to switch between the mouse and keyboard too often. There are a handful of standard techniques that designers can use to avoid this issue. It is common to implement keyboard shortcuts and standard keys for standard functions [11, p.11-26].

A final important aspect of human behaviour is that we are social, we care what others think. This includes when we test and use an interface. If, for example, more experienced colleagues dislike a part of a software system, the less experienced in general feel the same way [11, p.11-26].

2.3.5 Workflows and tasks - Important design choices

As stated earlier, SCADA systems have broad functionality and their interface need to display massive amounts of data and give the operators proper ways to control the system as a whole [4]. When designing an interface with the purpose of using workflows and clearing tasks, there are some general design pointers, often based on previous research and analysis, such as flow diagrams [11, p. 33].

The first principle is to **design by frequency of usage**. By analysing which tasks are the most common to perform and to repeat, the designer can improve the experience by making these tasks readily available, while tasks that are less common can be accessed through more specific navigation [11, p. 33].

The second way to compose a task and a workflow dominant program is to **sequence** tasks into smaller steps. If a task is overwhelming for a user, it is possible for the designer to sequence it into several less complicated steps and give users more flow. An important aspect of sequencing is that different users have different levels of experience using a specific system or similar systems. A designer should consider both how a first-time user would react to a single task or a specific sequencing, as well as what a more experienced user would need to use the system more efficiently [11, p. 34].

Frequency and sequencing go hand in hand to create a more positive user experience, yet it is also important to note that users most likely experiences the system from numerous channels, such as screen sizes or with/ without touch functionality. Designing the interface based on how and where users will have access to it is important and should be accounted for in the research stage [11, p. 34].

2.3.6 Layout

The layout is the way different elements are arranged to create the whole site, frame, or system. If a designer is mindful of where and how to display functional, informative, and purely decorative elements, they may create a clean layout. To do this, there are some basic principles that need to be followed. Three of these are **visual hierarchy**, **visual flow**, and **dynamic displays**. These principles are related and sum up to:

1. Visual Hierarchy - The more important an element is, the more it should stand out, relative to each other.
2. Visual Flow - Understanding what the reader sees and emphasises on then scanning a page
3. Dynamic displays - Considers the interaction between a user and the site, what dynamic aspects that can be used to give the user a better flow when using the system [11, p. 209-226].

Both visual hierarchy and visual flow are important parts in both static and dynamic layouts, whereas dynamic displays is a principle purely for interactive systems. Visual Hierarchy can be achieved by sizing, position, density, changing background colours, rhythms, emphasising small elements, and by using grids and alignments. A set of psychological principles in this area are called the **Gestalt Principles**. Visual flow can be achieved by constructing and manipulating focal points, using implied lines, and call to action. For dynamic displays, useful tools are, for example,

scroll bars, responsive enabling, and progressive disclosure [11, p. 211-225].

It is also important to consider different user interface regions, these are:

- Title / Header - Often constant, containing global branding and navigation
- Navigation / Menu - Can be panels and are usually at the top or to the left
- Main content domain - Uses up a large part of the screen, to showcase the information, tasks and more
- Footers - To have at the bottom for excessive navigation or general helpful information
- Panels - Can be used statically or dynamically for further functionality

More concretely, there are design patterns to create a clean layout. Three of these patterns are **Visual Framework, Center Stage, and Grid of Equals**. A **Visual Framework** is used for complete interfaces to sustain characteristics and themes across the entire interfaces. It is important to have a visual framework when building an interface which consists of multiple parts or pages, so that users can see that they are using the same system the entire time they are in it. This is done by consistently using colours, fonts, grammar, layouts, and other UI tools. To use a visual framework also causes designers to separate artistic design choices from the content which needs to be displayed. One way to display this content is to use the pattern **Center Stage**. To display one singular portion of information fully centred to let the user's immediate attention go there. In comparison to that, there is also **Grid of Equals**, which instead organises equally important content equally in the main content domain so that the user may choose to click further to where they want to go.

Even more specifically, where are important UI tools, which are used when a system contains loads of information, which needs to be clustered or ordered are **collapsible and movable panels, titled sections, module tabs, and accordions** [11, p. 226-237].

These layout patterns and the possible implementation of these are studied in the static analysis of the current system to assess how these are implemented. The implementations' effectiveness was studied during the evaluation which, in the end, informed the re-designs made. The layout patterns were also used when making decisions in the re-design stage.

2.3.7 Colours

Colours are a fundamental part of visual design. Choosing different colours and palettes can both direct moods of users while different colours have different pre established meanings for users by habituation. [15, p.141-142]

A designer should not rely on colours alone, although when it comes to colours it is important to note whether the colours are warm or cool, the background is light or dark, the contrast is high or low, the colours are saturated, or unsaturated and their combination of hues.

Different choices in colours give different effects for users, such as whether the page is calming to look at, easy to read, or awakening [11, p. 258-264].

The current systems colours were studied during user evaluations which in turn informed the design choices and recommendations made.

2.3.8 Navigation

Navigation is used to help the user understand where in a UI they are, how to get where they want, and how to get back. Wayfinding is how they do it and three common features are good signage, environmental clues, and maps. That is, to have explicit clear labels, use "calls to action", use culturally determined cues, and help the user gain mental images.

When designing a system, the designer also makes decisions on how to isolate the navigational design from the visual design, what the cognitive load for a page should be, and how to keep the distance from page A to page X short. Therefore, there are navigational models to choose from. The ones studied are described below in following passages and in figure 2.1. There are more ways of designing navigations, but these were not relevant for the study.

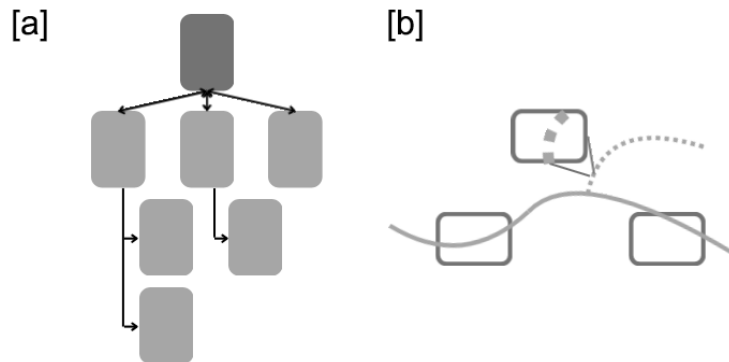


Figure 2.1: Navigation models

Tree or Multilevel navigation [a] is perhaps not as common on mobile devices, but on websites it is. Beginning with a homepage, it is possible to reach every other main page, yet subpages are only visible when on the main page for that category. This is commonly used in enterprise web software, often for combining many different applications into one larger. Pan and zoom navigation [b] is most commonly used for maps and similar sites, where a large item is displayed and there is a possibility to pan and zoom to gain more insight. Lastly, flat navigation is when navigation is barely needed or even needed at all. An example of this is Photoshop, where the user is mostly in the same space during the entire experience [11, p. 129-208].

In this project, navigational models were used to help describe the current navigational paradigm in the system. It is also studied whether the current chosen model is effective and whether users could find their way.

2.4 ACM Code of ethics

The ACM code of ethics is a set of general ethical guidelines designed to be used by anyone in computing [16]. The code has four parts where part one is pertaining to the functionality and accessibility of software, part two is about professional

conduct, part three is about leadership and how to lead ethically, and part four is about praise and enforcement. These guidelines serve as a base for further ethical reasoning during a project.

For this project, parts one and two are the main focal points where part one will be applied and studied as part of the validation of the product, and part two will be used during the process of creating for professional conduct.

2.5 Envisioned user goals and tasks

According to the developers of the system [17] "The main functions of SCADA systems" are:

- HMI or Human-Machine Interface, displaying a graphical visualization of the technical processes and the ability to interact with these processes by issuing control commands.
- Alarm handling. Status values in the monitored systems are constantly checked and when these values meet certain criteria, alarms can be raised. These alarms are presented to the users of the SCADA system in such a way that the problem and required action is clear.
- This is the process of collecting pre-defined data from the monitored systems and displaying it on the screens.

The tasks a user should be able to perform gathered by looking at the system documentation[17] are as follows:

- The users should have an digital overview of the physical system as a map of the baggage handling areas. A general overview as well as specific areas both for arriving, departing and special bag flow. This map should be as close to reality as possible.
- The system should also alarm the user of errors, giving a description of the error and where in the facility it is.
- The user should be able to start, stop, reset and see if a specific part, such as a conveyor belt, is in automatic mode, manual mode or offline.
- The user should also be able to see if a process is full, queued, working or offline.
- The user should be able to see a history of events, alarms and errors.
- The user should be able to alter the check in mode for both all desks or a specific one. They should also be able to alter load balancing of the facility, see bag flow (with counters) and see which bags are in stuck in a loop.
- The user should get real time updates and be able to see real time executions.
- It should be possible for the system to have multiple users.
- The system should log the user out after a set period of inactivity.

These tasks will be used as a building ground for further evaluation of the system and for additional requirements knowing what is already in place.

3

Method

The project is dependent on many variables and the small workforce is one, therefore the data gathering was mainly done in a qualitative manner. The system studied was also complicated with many moving parts requiring some prerequisite work. The general method was centred around a static analysis, observations, interviews, and a User Experience Questionnaire (UEQ) [18]. The latter three were carried out on different members of the baggage handling staff at different times.

Splitting the evaluation into the methods mentioned above was done due to access since they needed to be done on premise. This was done to gain an understanding of how the software worked before any evaluation was made. Using observations and interviews was chosen because it gives a broad understanding of how users interact with the system and what needs to be improved [11, p.8-11]. This is explained later in the Chapter. Lastly, the UEQ survey was chosen as an alternative method to gather more data in a short period of time.

The study was planned, almost in its entirety, in a study design document. The purpose of this was to align the group's members in terms of method and to document the process of UX evaluation. Documenting this process aids in further creation, validation, and implementation of the software [19].

Documentation of results was conducted using text for the observation and interviews and a specific interpretation method for the survey. Textual documentation such as interview transcripts and observational notes is frequently used in coding for thematic analysis which was carried out as part of the analysis of the collected data [20].

3.1 UX evaluation in general

There are many different ways of evaluating a user experience. Users can self-report issues through answering surveys or interviews either at the prompt of the researcher or by reporting their experience through some sort of feedback form. Another form of evaluation is observational evaluations where researchers observe people using the product. A less frequent evaluation method is the method of psychological evaluation which assesses metrics such as stress through indicators found psychologically [21].

Observational techniques include both more quantitative approaches such as measuring performance or click rate as well as more qualitative methods such as participant observation a method which is described in the sections below [22][23].

The most common way of evaluating user experiences is according to Inan Nur et al. after usage of the product and through self reporting methods. However, for

observational methods the most common place and time of evaluation was during use [21]. The methods in this study follow both observational as well as self reporting methods with more focus on the observational methods as these are more time consuming [24].

3.1.1 Why observations and interviews?

The choice of observational and self reporting techniques in unison, observations and interviews, was multi faceted. Interviews provide rich data and are an opportunity to collect a large amount of meaningful data while being able to adapt and tailor the format to the person being interviewed [24]. They also open up for the subject to be able to explain the context of their actions making uninitiated researchers able to understand the user's actions. Observations on the other hand do sometimes require some initiation but can be combined with interviews for a more complete picture. Combining observations with interviews ensures the context of the interaction is taken into account [25].

3.1.2 Challenges

Interviews however, do introduce a dimension of subjectivity which is hard to control, therefore the quality of the data relies on factors beyond the actual product such as the user's mood or agenda other than the want for a usable system [26]. It can be argued that an adverse interviewee can drastically affect the outcome of studies especially when there is a low amount of participants. However, the subjectivity can also be used to an advantage as discussed before being able to catch the entire picture of a system. There is also the issue of bias from the interviewer especially when interpreting the data gathered. This bias will later be discussed under the subsection of data analysis 3.9.

Another challenge is the time it takes to conduct, interpret and present interviews and observations. As opposed to more quantitative methods interview require lots of hands-on time [24]. This time includes both actually conducting the interviews but there is also time spent doing things which are not productive towards gaining any insight such as transcription and the logistics of booking and transportation. A possible mitigation for the latter two would be doing digital interviews and observation which have proven effective during the Covid-19 pandemic [27]. Although, due to the security implication of this project no such arrangement was possible.

Even though there are some challenges the strength of the data collected as well as the small amount of available participants made these methods the most viable.

3.2 Phases

The project was divided into parts. Initially, a study design document was created and a planning stage was conducted, and from that a project plan was formed. At this stage, observations and interviews were planned. At this time a read-through and pattern analysis of the current system's documentation was also held.

Then, there was an execution phase where interviews and observations were conducted. This was done together with distributing surveys to workers. After the information was collected, the interpretation of the answers was carried out through a thematic analysis. This was later validated in pairs.

Finally, the product was put together. The analysis was visualised, and new design proposals were made and later validated both internally and with the company. Together with the design proposals, some functional and non-functional requirements were also produced from the analysis.

3.3 Participants

The participants of the observations and interviews were homogeneous mainly consisting of men over 40 years old with mid- to high knowledge of computers. This was due to the availability of staff, where most people working with the system consisted of this demographic. This also meant that the survey respondents also consisted of this demographic.

3.3.1 Criteria

Participants chosen for the interviews/observations were required to use the SCADA system as an administrator/operator and to be a member of the BHS team at the airport. The participants were also required to have the need to use the system in their work and to be authorised to view and use the system. Participants were not selected based on age or gender, and no consideration was made beforehand on their computer proficiency even though this was logged for possible analysis.

3.3.2 No. of participants

The total number of participants for interviews and observations was seven. Six of them were regular users, and one was a new hire who was younger and had less experience.

For the survey, the entire technical division, which consists of around seventeen people, was asked to answer. However, only seven people responded to the survey.

3.4 Materials

The main work of the participants was completed on the company's own machines using the production version of the software. For the interviews some questions were posed where opinions of colour schemes and error messages were evaluated. A printout of these was used as a visual aid for the participants.

As far as materials used for recording the data. A computer or pen and paper was used to take both field notes and to protocol the interviews in as detailed fashion

as possible. The voice recorder on one of the interviewer's phone was used to record interviews for later transcription.

The interview questions as well as the observation templates were structured in one document which can be found in Section B.

For re-designs the digital prototyping tool Figma was used to make interactive digital prototypes of UI suggestions.

3.5 Static UX Analysis

Before conducting the user studies in the form of observations, interviews, and surveys, a superficial UX analysis was done to understand current design choices in the SCADA system from the documentation [17] and screenshots. This was done by comparing the SCADA system with the patterns and best practices described in the theoretical background. Each screen was reviewed and possible design patterns were identified. The analysis was used to make interview questions and scenarios which can be found in Section B. The analysis was also used to inform design decisions made on the screens.

3.6 Observations

Observations were used to gather information about user behaviour in the systems at work. These were carried out during one hour of work. For the observational studies data has been collected through writing notes with pen and paper. Observations were made in pairs or as a group of four researchers. Working together in groups or teams has multiple benefits while doing observations: It ensures that different perspectives are captured, it makes the data more reliable since it can be compared to what observations were made, it is possible to focus on different parts if needed, and it is easier to reflect and compile the data if there was more than one observer [28, p. 291].

During the observations, another staff member, besides the one being observed, was also present as a **key informant**. MacHado et al. [29] describes a **key informant** as a necessary tool in hands-off observations to not intrude into the participants' work. A **key informant** acts as an expert voice answering questions and concerns mid-observation. This meant that the member observing the participation could stay out of the way.

The observational method was borrowed from participant observation [30]. This method describes an immersive and unobtrusive way of observing cultures and people partaking in, or overlooking, activities without any input or guidance. In this case, these were done by some members of the group partaking in work as an employee, and others passively observing this act.

The protocol for individual observations can be found in Section 3.6.

3.7 Interviews

Directly after each observation, an interview was conducted with the same participant. Interviews were split up into two parts. The first part used the method of contextual inquiries, which is a method of observing or interviewing a user while they perform pre-determined tasks relevant to the material that is being analysed [31]. This was done by going through three different general contexts: navigation, error messages, and textual/colour choices, and asking the user to think aloud describing how they completed these tasks.

The second part of the interview focused on the user themselves. The participants were asked to describe and reflect on their experiences both working with the system long-term as well as doing the specific tasks posed to them in the contextual inquiries. This method mimics the method of phenomenological interviewing [32] suggested for eliciting domain specific requirements in safety-critical contexts [33]. The users were also asked to match existing system colours to specific status messages printed out on paper based on their preference, and then rationalise this choice.

One of the observers acted as a note taker while the other one asked questions. The questions were partly generated from the UX analysis Chapter 3.5, but also consisted of general questions about the participant. Open ended questions generated from the observations were also asked, to help fill in gaps that might have emerged during the observational stage. In addition to taking notes during the meeting, the interviews were also recorded for further transcription before analysis. The recordings were then deleted.

The interview questions can be found in Section B.

3.8 Surveys

To get a broad range of data, the project included surveys that were sent out to staff members both physically and digitally in hopes of getting as many answers as possible. The survey was a User Experience Questionnaire which is a standardisation on how to measure satisfaction in a system. It is a predetermined set of questions filled out on a scale where the users rate the systems', for example, "attractiveness" vs. "unattractiveness" and "motivating" vs. "demotivating" [18]. The survey questions can be found in the appendix in figure D.

3.9 Analysis of the data

After the gathering, all data from the UEQ was interpreted according to the provided analysis sheet [18] and the recordings of the interviews were completely transcribed. An analysis of both data types was initiated, beginning with thematic analysis of the qualitative data (the observational notes as well as interview transcripts).

Working with qualitative data from interviews and observation, thematic analysis was used to identify patterns and general themes, to find common answers and opinions, as well as to fill out the more qualitative observations. This partially

followed a five step process as described by Braun and Clarke in [34]. The data was first thoroughly read through to familiarise the coders with the content. This was also done to catch errors in transcription. Doing this in pairs improves the creditability of the data processing and helps to avoid bias [35]. The next step was to code the discussions using natural language to describe things, such as uncertainty in some area. The data was then grouped into larger themes. The themes were then reviewed. This was done in two steps. First, the themes were looked at in isolation, making sure that the codes they contained were coherent. Next, themes were compared to the entire dataset, making sure the themes are relevant to the entire dataset. Themes not fitting this criteria were either reorganised by deleting them, merging them, or breaking them down into subthemes. To finalise the thematic analysis, codes and themes were linked directly to specific parts of the system derived from the observations so that opinions about specific parts could be structured.

3.9.1 Creating requirements

In addition to the themes, the interview transcripts were also looked into for missing functionality as well as some aspects of functionality that did not work in a satisfactory way. From this feedback a set of new requirements were created. Twelve functional and nine non-functional requirements were created. The reason for the small size of new requirements was the previous existence of well-documented requirements for the core functionality [17].

3.10 Creating UI Analysis and screens

After the data interpretation, the codes and themes from the interviews, as well as the quantitative results from the UEQ were studied in conjunction with the actual transcripts of the interviews and earlier requirements. These results, as well as the static analysis Chapter 3.5 informed the design decisions made to improve the system. These were done both as a prototype in Figma and in text to further explain functionality that was not suited for prototyping.

Technical research on patterns also inspired patterns. Not only the previous patterns identified were used, but also design patterns found in literature were used to achieve the wanted outcome specified by the results of the surveys, interviews, and observations.

3.11 Validation

Validation was carried out in three distinct steps:

1. Peer reviews of coding and conclusions drawn from the qualitative data.
2. Checking the designs and requirements against the Association for Computing Machinery(ACM) code of ethics[16].
3. Company validation in the form of interviews with the participants or coworkers of the participants where the redesign was shown and feedback was col-

lected.

The peer reviews were done by swapping coding with another pair who did another set of observations and interviews so they could look at it without the full context of having conducted the interview and observation.

Validating designs and requirements against the ACM code of ethics was done in pairs, making sure that any documented decisions made were in line with these guidelines.

The validation interviews were conducted in a think aloud way where seven of the coworkers at the baggage handling division were asked to try the newly made prototype. First, they got to navigate the prototype and talk aloud. After that, they were shown the prototype side by side and changes were explained to highlight the ones missed. The subjects were also told about changes that could not be implemented in the prototype mainly pertaining to keyboard usage, sounds, and some functional requirements. This data was then analysed in a qualitative way, where smaller suggestions for change were adapted as changes to the final prototype. Also, some specifics of interactions were suggested, such as what quick keys should be implemented.

3.12 Informed consent

During the study, a contract for informed consent was distributed as seen in Chapter A among participants to agree to where the purpose of the research is stated in clear language and participants are informed that they are opting in to their data being used for this study. They are also informed that this consent can be withdrawn at any time. Miller and Boulton mention that the notion that opting in to research instantly makes the participant empowered and autonomous, as well as completely informed, is not necessarily true [36]. One should not assume that any informed consent form is enough, and individuals choices are affected by many different aspects such as cultural and workplace notions that one should keep consenting. There may also be pressure for the opposite, where legislation and increased debate around personal data collection are weaponised and commercialised[36].

In conclusion, a mere contract and some textual information was not enough to assume all participants are properly informed; therefore, continual contact with the participants was kept informing them about steps in the project to keep trust to a maximum.

4

Results

The results examines users' thoughts and actions in the existing system, what patterns are used, the design decisions made, as well as the results from the design validation.

The first part, Patterns Used, is the result of the static UX analysis of the user interface conducted by the group, examining key aspects such as layout, navigation, colours, and behavioural patterns, including visual hierarchy, dynamic displays, and user interaction principles.

In the second part, findings are presented from both the qualitative and quantitative analyses conducted in the study. Thematic analysis was used to explore participants' open-ended responses, identifying key themes that reflect their experiences and perceptions. In parallel, the User Experience Questionnaire (UEQ) [18] provided limited quantitative insights into users' evaluations across various dimensions, but where too random to be able to form complete conclusions from that data. The combined findings then led to re-designs of some UI elements.

Additionally, several functional and non-functional requirements have been identified as part of the system's improvement process. While these do not form a full software requirements specification, they provide enhancements based on the UX re-designs.

4.1 Patterns used

In this section, patterns mentioned in the background will be used to describe the current UI and the design choices made by the previous developers.

4.1.1 Behavioural Patterns

The well implemented patterns are:

- The **Safe exploration** pattern has been applied in many areas of most pages, such as those containing a map seen in Figure 4.1 such as being able to click around the green tracks without them stopping. The user has to input commands like pressing "stop" to stop a specific conveyor, this is also true for starting them.
- The **instant gratification** pattern is considered in the system requirements [17] citing a total of three second response time from action to reaction.
- The user can switch between errors mid-task by clicking the event in the list at the bottom of the page as seen in Figure 4.1, which is an application of the

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Change in midstream pattern.

- When an action is acknowledged, meaning marked as done in the system, the user can access it through the same action described above, with **Change in midstream** pattern. This is an application of the **deferred choice** pattern. However, one might have to look for the acknowledged alarms on the error page as seen in Figure 4.2.

4.1.2 Layout

- The main part of, for example, the departures page seen in figure 4.1 is the green map, which stands out in terms of colour and is surrounded by white space. This follows the heuristic of **visual hierarchy**. The most important active errors/alarms are also shown at the top of the list of events at the bottom of the same screen.
- The screen is updated automatically on event which follows **dynamic display**.

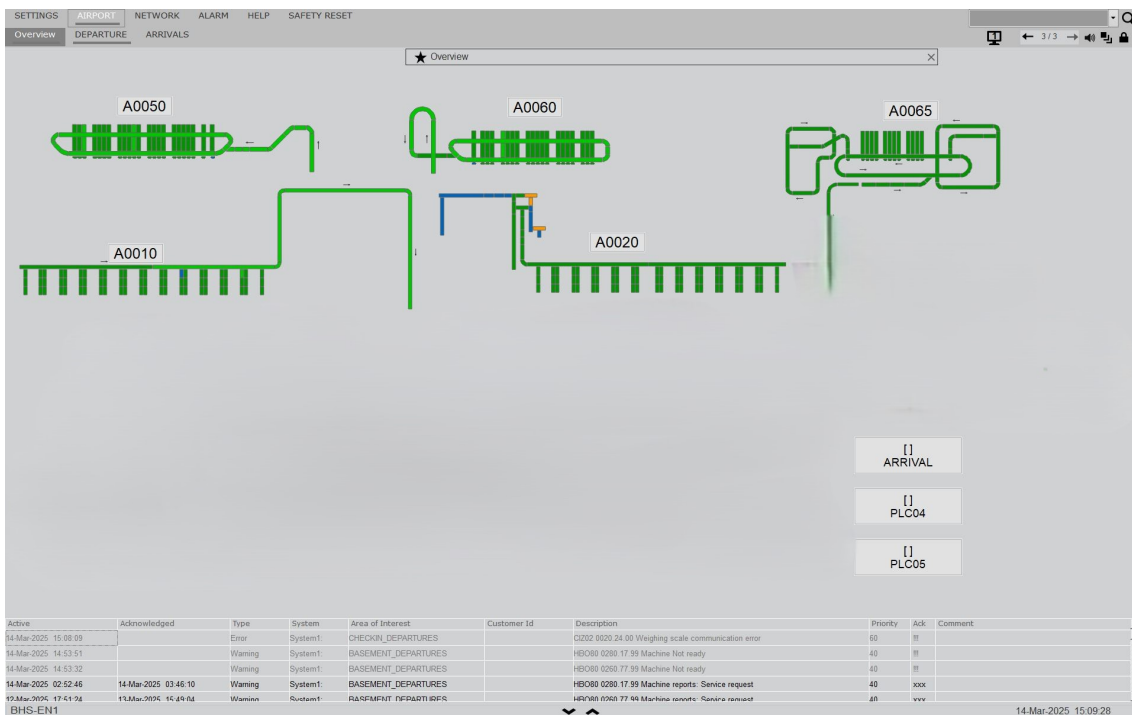


Figure 4.1: SCADA system overview map view of the departures. Adapted with permission.

Active	Acknowledged	Type	System	Area of Interest	Customer Id	Description	Priority	Ack	Comment
14-Mar-2025 15:08:09		Error	System1	CHECKIN_DEPARTURES		C202 0200 34 09 Weighing scale communication error	60	#	
14-Mar-2025 14:53:51		Warning	System1	BASEMENT_DEPARTURES		HS080 0260 17 99 Machine Not ready	40	#	
14-Mar-2025 14:53:32		Warning	System1	BASEMENT_DEPARTURES		HS080 0260 17 99 Machine Not ready	40	#	
14-Mar-2025 02:52:46	14-Mar-2025 03:46:10	Warning	System1	BASEMENT_DEPARTURES		HS080 0260 17 99 Machine reports: Service request	40	xxx	
12-Mar-2025 17:51:24	13-Mar-2025 15:49:04	Warning	System1	BASEMENT_DEPARTURES		HS080 0260 17 99 Machine reports: Service request	40	xxx	
07-Mar-2025 05:22:32	18-Mar-2025 03:45:30	Warning	System1	BASEMENT_DEPARTURES		DF200 0250 67 00 Semi-automatic mode fixed straight	40	xxx	
07-Mar-2025 00:48:08	07-Mar-2025 04:19:34	Warning	System1	BASEMENT_DEPARTURES		HS080 0250 73 99 Machine reports: Service request	40	xxx	
23-Feb-2025 04:54:46	24-Feb-2025 14:25:59	Warning	System1	BASEMENT_DEPARTURES		LRJ31 0270 53 03 End of section PEC bad tracking	40	xxx	
20-Jan-2025 10:57:15	20-Jan-2025 11:01:35	Warning	System1	BASEMENT_DEPARTURES		LWC31 0240 80 01 End of section PEC bad tracking	40	xxx	
25-Oct-2024 13:14:37	26-Oct-2024 03:41:45	Warning	System1	CHECKIN_DEPARTURES		BF01 0020 52 01 PEC-1 Bad Tracking	40	xxx	
25-Oct-2024 13:14:34	26-Oct-2024 03:41:45	Warning	System1	CHECKIN_DEPARTURES		BF01 0020 52 02 PEC-1 Bad Tracking	40	xxx	
21-Jul-2024 22:31:19	22-Jul-2024 06:52:20	Warning	System1	BASEMENT_DEPARTURES		TB31 0280 35 01 End of section PEC bad tracking	40	xxx	
12-Apr-2023 14:12:19	12-Apr-2023 17:54:14	Warning	System1	CHECKIN_DEPARTURES		BF01 0020 51 01 PEC-1 Bad Tracking	40	xxx	
12-Mar-2025 17:15:09	12-Mar-2025 17:15:15	Error	System1	BASEMENT_DEPARTURES		HS080 0250 73 99 Machine reports: Unavailable for scanning	60	x	
11-Mar-2025 02:51:40	14-Mar-2025 03:39:02	Error	System1	BASEMENT_DEPARTURES		HS080 0250 73 99 Machine reports: General fault	60	x	
07-Mar-2025 12:19:42	07-Mar-2025 12:19:46	Error	System1	CHECKIN_DEPARTURES		BF01 0010 18 03 MS Not in automatic	60	x	
07-Mar-2025 12:19:42	07-Mar-2025 12:19:47	Error	System1	CHECKIN_DEPARTURES		BF01 0010 18 03 Thermal overload	60	x	
07-Mar-2025 05:23:13	07-Mar-2025 05:23:17	Error	System1	BASEMENT_DEPARTURES		LRJ31 0250 67 00 LMS not in automatic	60	x	
26-Feb-2025 07:58:41	26-Feb-2025 07:58:47	Error	System1	MAKEUP_DEPARTURES		LCC01 0065 00 79 Fieldbus Slave error	60	x	
26-Feb-2025 07:58:21	26-Feb-2025 07:58:52	Error	System1	MAKEUP_DEPARTURES		BSS01 0065 04 99 Fieldbus Slave not Present	60	x	
24-Feb-2025 21:30:50	24-Feb-2025 21:31:07	Error	System1	CHECKIN_DEPARTURES		BF01 0020 52 02 MS Not in automatic	60	x	
24-Feb-2025 21:30:50	24-Feb-2025 21:31:14	Error	System1	CHECKIN_DEPARTURES		BF01 0020 52 01 MS Not in automatic	60	x	
23-Jan-2025 16:56:43	23-Jan-2025 16:57:06	Error	System1	MAKEUP_DEPARTURES		DPP01 0060 11 01 Not Automatic	60	x	
27-Feb-2025 16:05:14	27-Feb-2025 16:05:52	Warning	System1	BASEMENT_DEPARTURES		DF200 0270 53 00 Semi-automatic mode fixed straight	40	x	
06-Nov-2024 04:43:55	06-Nov-2024 04:46:21	Warning	System1	CHECKIN_DEPARTURES		BF01 0020 52 04 PEC-1 Bad Tracking	40	x	
26-Aug-2024 09:16:27	26-Aug-2024 10:19:45	Warning	System1	CHECKIN_DEPARTURES		BF01 0020 52 03 PEC-1 Bad Tracking	40	x	

Figure 4.2: The error page which shows all the alarms. Adapted with permission.

- In terms of **regions** there are
 - Headers
 - Navigation bar
 - A separation of the main part
 - * Current page indicator
 - * There are some information panels as well as a bottom event panel which can be seen in Figure 4.3.
 - There is a footer with a log out button, alarm arrow buttons and date/time.
- The developers have specified a **visual framework** in terms of colours, fonts, and the boxed layout which is followed at points throughout the system. However, there are places where buttons do not look alike, such as the arrivals section seen in Figure 4.3 as compared to the check-in section seen in Figure 4.4.
- The most important aspect of the software, the map of the baggage bands, is large and in the centre of the screen which follows the **centre stage** pattern.

The user can **pan and zoom** around the main baggage bands shown in most screens showing maps such as those in Figure 4.1 and Figure 4.3. The header of these pages implements the **Tree/multilevel navigation** pattern which is applied in the entire system being able to backtrack from submenus like the ones shown in Figure 4.3.

The overall colour scheme works in greyscale. It uses low contrast for unimportant things while active events and tasks stick out more using both solid black and colours like red and green shown in the appendix in Figure E.3. The colours for communicating the status of a band (green in the general map seen in Figure 4.3)

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are classified in Table E.2.

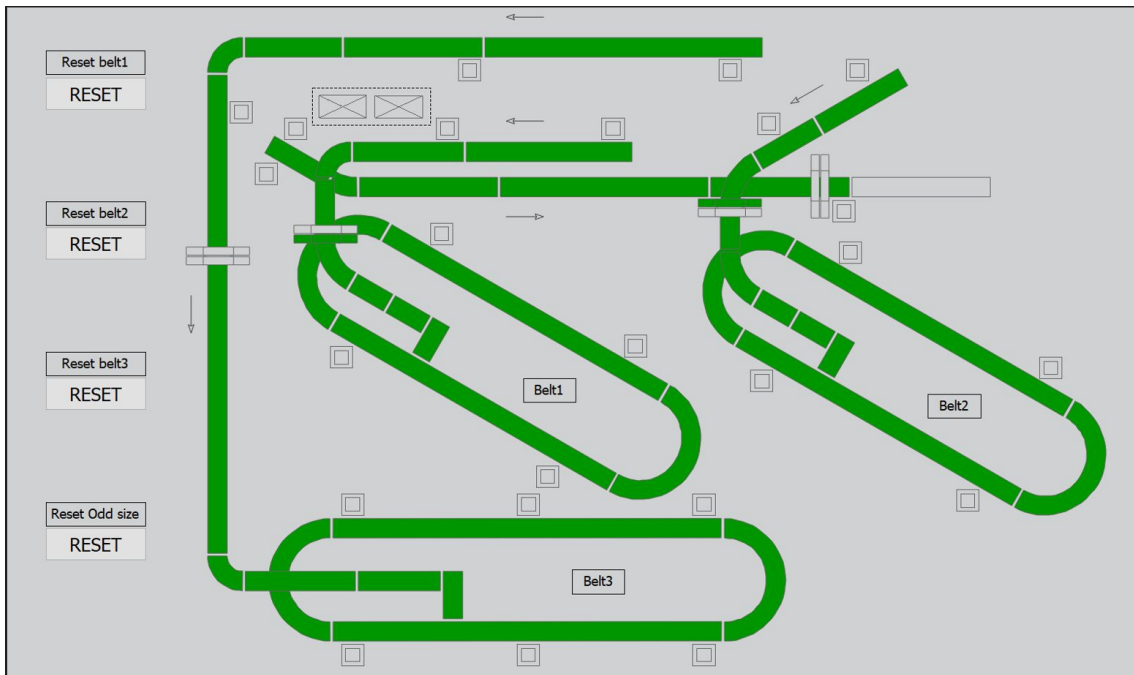


Figure 4.3: SCADA system map overview of the arrivals chapter. Adapted with permission.

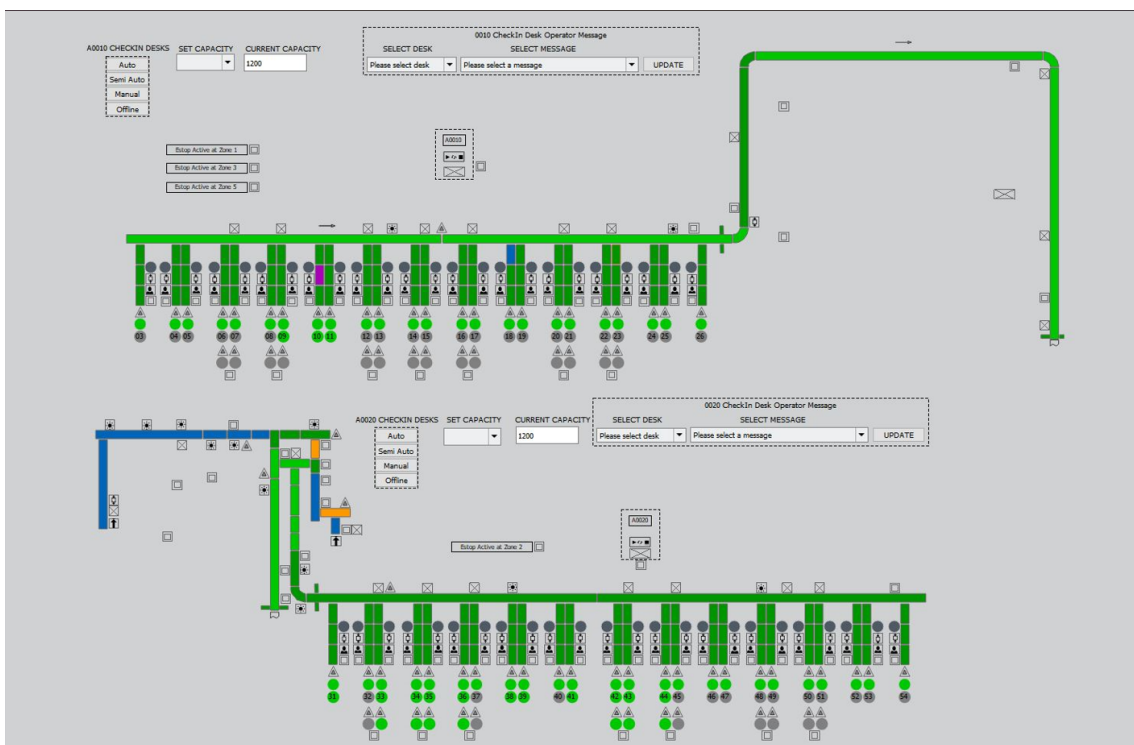


Figure 4.4: The check-in conveyors. Adapted with permission.

4.2 UEQ results

The User Experience Questionnaire was handed out to workers at the baggage handling division to answer physically. Seven responses were gathered from these forms. The answers are to be interpreted as a negative value corresponding to "left" and a positive value corresponding to "right". A mean above 1 is considered significant in any direction. The results can be found in Table 4.5.

Mean	Variance	Std. Dev.	No.	Left	Right	Scale	
-0,1	1,5	1,2	7	annoying	enjoyable	Attractiveness	
-0,1	2,1	1,5	7	not understandable	understandable	Perspiciuity	
-1,0	0,3	0,6	7	creative	dull	Novelty	
0,6	5,3	2,3	7	easy to learn	difficult to learn	Perspiciuity	
1,1	1,5	1,2	7	valuable	inferior	Stimulation	
-1,0	1,3	1,2	7	boring	exciting	Stimulation	
0,3	1,2	1,1	7	not interesting	interesting	Stimulation	
-0,1	5,1	2,3	7	unpredictable	predictable	Dependability	
-0,6	4,3	2,1	7	fast	slow	Efficiency	
-0,3	0,9	1,0	7	inventive	conventional	Novelty	
1,0	1,7	1,3	7	obstructive	supportive	Dependability	
0,1	2,5	1,6	7	good	bad	Attractiveness	
0,1	3,8	2,0	7	complicated	easy	Perspiciuity	
0,9	2,5	1,6	7	unlikable	pleasing	Attractiveness	
-0,6	3,0	1,7	7	usual	leading edge	Novelty	
-0,4	1,6	1,3	7	unpleasant	pleasant	Attractiveness	
0,1	2,5	1,6	7	secure	not secure	Dependability	
-0,7	1,9	1,4	7	motivating	demotivating	Stimulation	
-0,1	3,8	2,0	7	meets expectations	does not meet expectations	Dependability	
0,3	3,2	1,8	7	inefficient	efficient	Efficiency	
-0,9	2,8	1,7	7	clear	confusing	Perspiciuity	
0,3	2,2	1,5	7	impractical	practical	Efficiency	
-1,1	2,5	1,6	7	organized	cluttered	Efficiency	
-0,7	1,6	1,3	7	attractive	unattractive	Attractiveness	
1,1	1,5	1,2	7	friendly	unfriendly	Attractiveness	
-0,6	0,3	0,5	7	conservative	innovative	Novelty	

Figure 4.5: UEQ responses to physical survey

While the results show a tendency towards some qualities the means mainly stay in the middle varying at around ± 1 point. The general opinions seem to not be extreme in either direction. However, looking at the variances the data suggests that workers were not united in their opinion and since the sample size is not high enough a generalised opinion can not be formed. Some questions had low variance suggesting somewhat uniform answers. These questions were pertaining to creativity and novelty where creativity was positive and novelty was in the middle. There was originally a plan to send out a survey to a larger group of workers who were only viewers of the system but no data was able to be gathered from this. In summary, the results here are inconclusive and will not work towards any other conclusion than that opinions differ widely between workers.

4.3 Thematic analysis

The interviews and observations ended up with seven participants. Interviews were held with all seven participants and observations were made during their working hours. Due to this, some participants did other work duties during the observations and four out of seven participants were observed using the SCADA system. The other three did not use the SCADA system enough during the observation time to properly be observed. The anonymous participants can be seen in Table C.1 in the appendix.

The transcribed interviews as well as the observations were coded using 28 different main codes with some sub-codes being established for detail as well. The codes found can be found in Table 4.1. These were then put in to themes described by statements which were then classified into positive or negative sentiment in Figure 4.6. The codes were also categorised into what UI element they were pertaining to so that specific issues could be localised and visualising where larger sums of comments about the system were occurring as in Figure 4.7.

An element in the result is described as either an action, screen or specific part of the UI such as a header. Airport → overview, arrivals in Figure 4.3, departures Figure 4.1, help Figure E.4, network and settings are all screens. The header is displayed on top of all screens (it can be seen in Figure E.1) and the error bar is at the bottom of most maps. The info sidebar pop-up is shown when a user clicks on any actionable icon. Messaging check in desks and Emergency stop are actions a user can do in the system. Icons, new and old basement, and self baggage drop are all features shown in the map sections which control and display bags moving along the system. These can be seen in both arrivals and departures Figure 4.3 Figure 4.1. The global tag is for the entire system.

ID	Code	Description
1	Adaptation	The user feels the element adapts to their needs
2	Allows customisation	The element allows for customisation
3	Communication error	The user found errors in communication in the element
4	Communication of user error	The user is informed of an error that they have made
5	Confirmation from system	The element confirms a user's action is successful
6	content	The user feels content with the way something works
7	Contextual navigation	The user can use the context of surrounding items to navigate to specific parts of the element
8	Critique of layout	The user critiques the layout of the element
9	Different hitbox sizes	The sizes of hitboxes feel different to the user
10	Distrust in functionality	The user does not trust that something works
11	Domain Knowledge	The user feels like their specific domain knowledge helps them use the specific element
12	General confusion	The user is confused over the element in general
13	Hard to learn	The user has a hard time to learn how to use the element
14	Inconsistencies	The user experiences inconsistencies in the design of the element
15	Intelligible naming	Names of things that are displayed are thought of as intelligible in the element
16	Issues with visibility	The user has a hard time seeing certain parts of the UI element
17	Layout symbol confusion	The user is confused about the whereabouts and symbols of certain functionality
18	Critical Functionality	The user thinks specific functionality is critical for their use of the system
19	Need for strong communication	The user feels the specific element needs to have strong communication
20	Positional awareness	The user is aware of where things are located in the system
21	Praise of layout/icon	The user is happy about the layout/icon choice in the element
22	Preference of older system	The user prefers an older iteration of the system
23	Safe exploration	The user feels they can safely explore the element without causing any trouble or harming any functionality
24	Trial and error	The user feels that they have to trial and error to accomplish a certain task
25	Two way navigation	The user has two ways of navigating though the specific element
26	Unsafe exploration	The user does not feel safe exploring the specific element
27	Unused functionality	The element has functionality which the user does not use
28	Use of different system	For some actions, the user uses a different system not included in the scope of this project

Table 4.1: Short descriptions of the codes

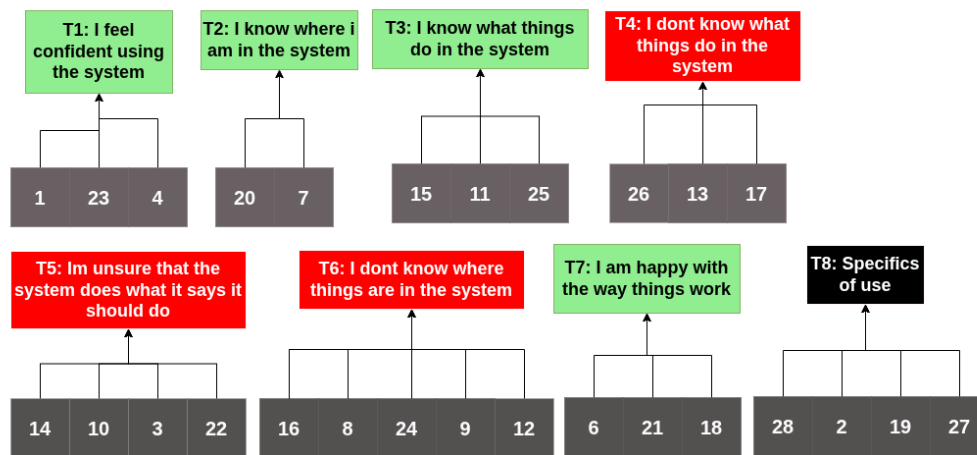


Figure 4.6: All Codes linked to their specific themes

The themes consist of four positive, three negative and one neutral theme. These themes later informed design decisions and requirements. The one neutral theme T8 just consists of some specifics of use with things like the users having to switch systems or that the system allows for customisation.

4.3.1 Positive themes

The first positive theme T1 consists of three codes and conveys confidence using the system. This was described by users as being informed of their actions and errors, being able to explore the system safe, and feeling like the system adapted to their needs. This was mainly observed when asking people about the effects of them making mistakes in the system which did not seem to bother them much at all.

The second positive theme T2 describes a feeling of knowing where one is in the system. Since most of the system is a map this is a crucial aspect of usability. Some users could map the real world well to the digital map and some could use UI tricks to help them find things. The latter is illustrated by the quote "If i have clicked on the alarm the part that is wrong starts blinking like this and i can easily find it" by P1.

T3 is also a positive code which is about the user being sure of what things do in the system. This was mostly due to names being clear and the users already having domain knowledge from having worked in the field for a long time. Users being able to directly describe what something does or how to do something was a sign of this.

The last positive code is T7 which is a form of content. This theme was made to illustrate that the user was happy with something or that they felt something should not be removed. It also includes places where the user says they like the layout.

4.3.2 Negative themes

The first negative theme T4 was found as a feeling of uncertainty of the functionality of some parts. This could both be in the form of some employees being scared to explore some elements in case they would do something that impeded operations. It was also found that some employees had a hard time learning how to use some elements.

T5 is close to T4 in the uncertainty aspect but focuses more on the actual functionality of the system. This one mainly concerns lack of feedback from the system and some inconsistencies in design as compared to the real world. One user said that "if you pull on the emergency brake in the basement the tracks that are stopped become blue but if it happens in some customer areas like the check-in tracks become white" which is an example of the above-mentioned inconsistency.

Lastly, the theme T6 is about users being confused of the whereabouts of some parts of the system either due to visibility or inconsistent layout and design, like some hit-boxes having a different size and some elements moving depending on the chosen view.

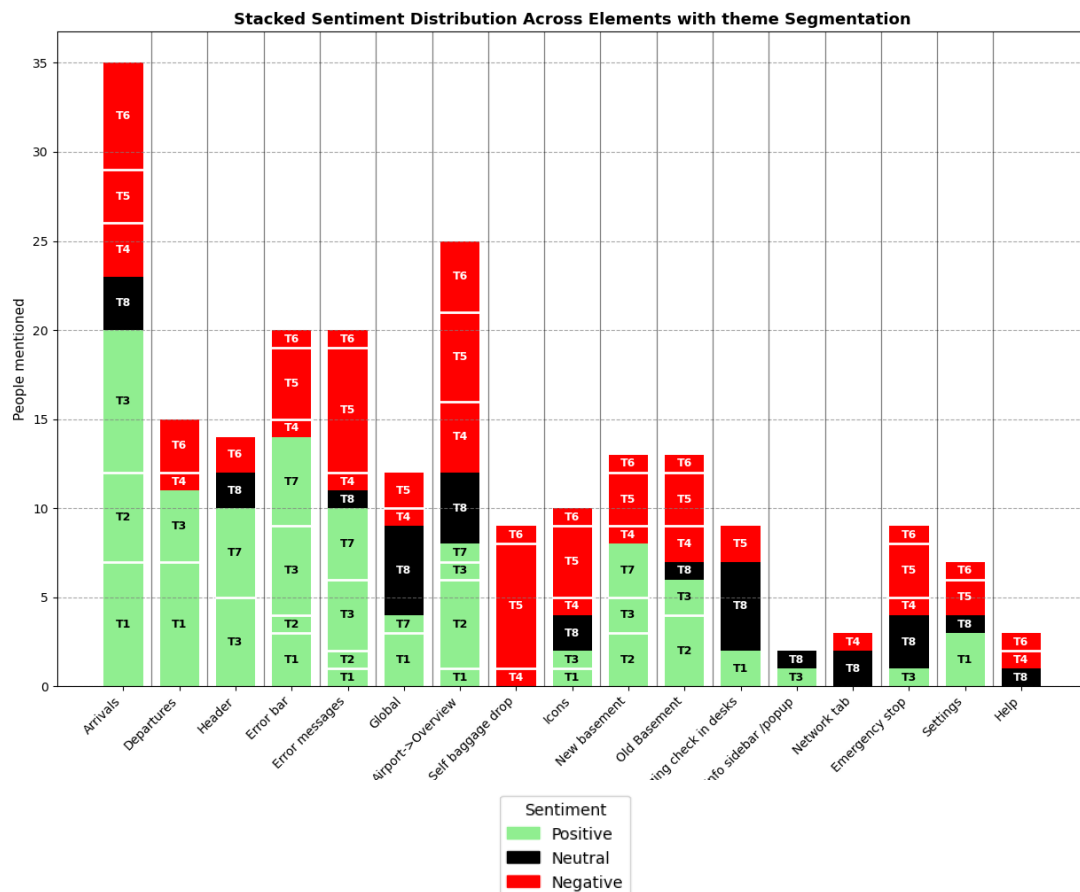


Figure 4.7: Bar graph of themes and elements in the system

Arrivals	"You sort of have to count backwards here from the carousel" - P1
Departures	"This is really the messiest area" - P5
Header	"I think its a bit confusion sometimes because the tabs look very different depending on where you are" - P1
Error Bar	"I would like to be able to change the text size depending on how many rows are displayed here" - P1
Network	"Right, over there. I would never dare to touch any of those buttons" - P6
Error messages	"I do not know what to think: It is okay i guess" - P6
Overview	"Here we have links to the arrival tracks but you can see them here, it's a bit of an emergency solution and not very clear" - P5
Self Baggage Drop	"Sometimes i forget and then the from desk calls and tells us to start it again"- P6
Icons	"In the overview, icons are very small" - P1
Global	"The software feels cheap and could be developed more" - P2

Table 4.2: Some quotes from the interview transcripts that describe the different UI elements. Translated.

To illustrate the general opinion of the elements, some quotes from the interview transcripts that describe them were removed. This can be seen in Table 4.2. There was also a trend, identified when coding, of employees preferring the overview page for general work. Therefore, a decision was made to recommend this as the front page of the application.

4.4 Colours

The interviewees were asked to arrange the map conveyor unit colours in a way that makes sense to them. Each map unit is a rectangle or other polygon on the map view for the visualisation of the facility as seen in the departure overview screen in appendix 4.1. The colours are based on the system requirements and documentation [17].

Error code	Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Majority occurrence
Not connected	Blue	Black	Black	Black	Black	Black
Offline	Blue	Black	White	Black	Blue	Black/blue
Safety stop	Yellow	Yellow	Yellow	Red	Yellow	Yellow
Full	Purple	Purple	Purple	Purple	Purple	Purple
Die back	Purple	Purple	Purple	Purple	Purple	Purple
Stopping	Blinking red	Blinking red	White	Blinking green	Blinking green	Blinking red/green
Energy saving	Light green	Dark green	Blue	Yellow	Dark green	Dark green
Stopped	White	Red	White	Orange	White	White
Error	Red	Red	Red	Red	Red	Red
Starting	Blinking green	Blinking green	Blinking green	Dark green	Blinking green	Blinking green
Externally stopped	Black	Blue	Blinking red	Blue	Blue	Blue
Started	Dark green	Light green	Dark green	Light green	Light green	Light green
Warning	Orange	Orange	Orange	Blinking red	Orange	Orange

Figure 4.8: Colours from the interview

Each interviewee was presented with a predefined list of conveyor states (e.g., starting, running, error) and was asked to assign a colour that they believed best represented each state. This process aimed to gather intuitive and user-preferred colour coding. Results are shown in Figure 4.8.

The “Majority Occurrence” column in the figure represents the most commonly selected colour for each state across the participants. There is a significant variation in colour assignments among different interviewees. However, some states, such as “error” and “warning”, tend to show higher consistency, often being associated with red and orange respectively. This suggests a common understanding of these colours as indicators of caution or danger. In contrast, states such as “offline” and “energy saving” show more variability, suggesting an ambiguity or lack of standardisation in these areas.

4.5 Requirements

From the study above some new functional and non-functional requirements were identified as a part of the system. These were not enough to fill an entire software requirements specification, rather they are an extension to the existing documentation and as an enhancement to the suggestions for changes made through UX re-designs. The requirements were elicited through the thematic analysis of the interviews and observations, as well as looking at the raw data directly. Thematic analysis helped identify areas where there were gaps in the current documentation. Looking directly at the data was helpful for writing precise requirements. In table 4.3 requirements are linked to the themes they aim to resolve.

Functional Requirement	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Themes	T8,D	T8,D	T6	T4	T4,T5	T4	T4,T6	T4	T4,T6	T4	T4,T6	T5
Non Functional Requirement	NF1	NF2	NF3	NF4	NF5	NF6	NF7	NF8	NF9			
Themes	T6	T6, T8	T6, T8	T4,T6	T5	T4,T5	T6	T8,D	T6,D			

Table 4.3: Functional and non functional requirement linked to negative themes they resolve. (D is for direct feedback from end user)

4.5.1 Functional requirements

- F1. Authorised users should be able to manually change the load balancing of track splits.
- F2. The user should be able to start individual conveyor units manually.
- F3. Unacknowledged alarms should be displayed until acknowledged.
- F4. Alarms that are not relevant for the current logged-in user should not be displayed.
- F5. It should be possible for a user to silence the sound of an active alarm without acknowledging the alarm.
- F6. All complete spellings of three-letter abbreviations should be up to date.
- F7. All complete spellings of three-letter abbreviations should be accessible to users.
- F8. All icon descriptions in the system should be up to date.
- F9. All icons descriptions in the system should be accessible to users.
- F10. All alarm messages should have their full description accessible to users.
- F11. All alarm messages should have their full description up to date.
- F12. The system should provide a visual indication when a conveyor is not in auto mode.

4.5.2 Non-functional requirements

- NF1. Description about specific conveyor units should be able to be seen from at least a distance of one meter on a standard¹ screen defined in [17].
- NF2. The system should be able to be comfortably used in dark environments.
- NF3. The system should be able to be comfortably used in bright environments.
- NF4. Active alarms should be visible from at least a distance of one meter on a standard screen defined in [17] after a maximum of one second of viewing.
- NF5. Conveyor units that are moving should have a clear colour distinction from those that are stationary.

¹Currently defined as a 16:10 aspect ration 27" screen

- NF6. All conveyor sections should be uniformly named.
 NF7. Conveyor units should be numbered sequentially based on their position.
 NF8. The system should be usable with only a keyboard.
 NF9. The conveyor sections should maintain their relative positions when selected.

4.6 Prototype in Figma

A Figma prototype was created to visualise suggested design changes to the current system. The prototype included redesigned screens for selected pages of the current system. Just as the requirements, this redesign was grounded in thematic analysis and raw data insights. The thematic analysis was helpful in determining which areas and pages needed the most change, and which needed to stay the same. Looking directly at the data helped in determining what specific design changes that were desirable. Below are some images of the prototype showcasing these changes.

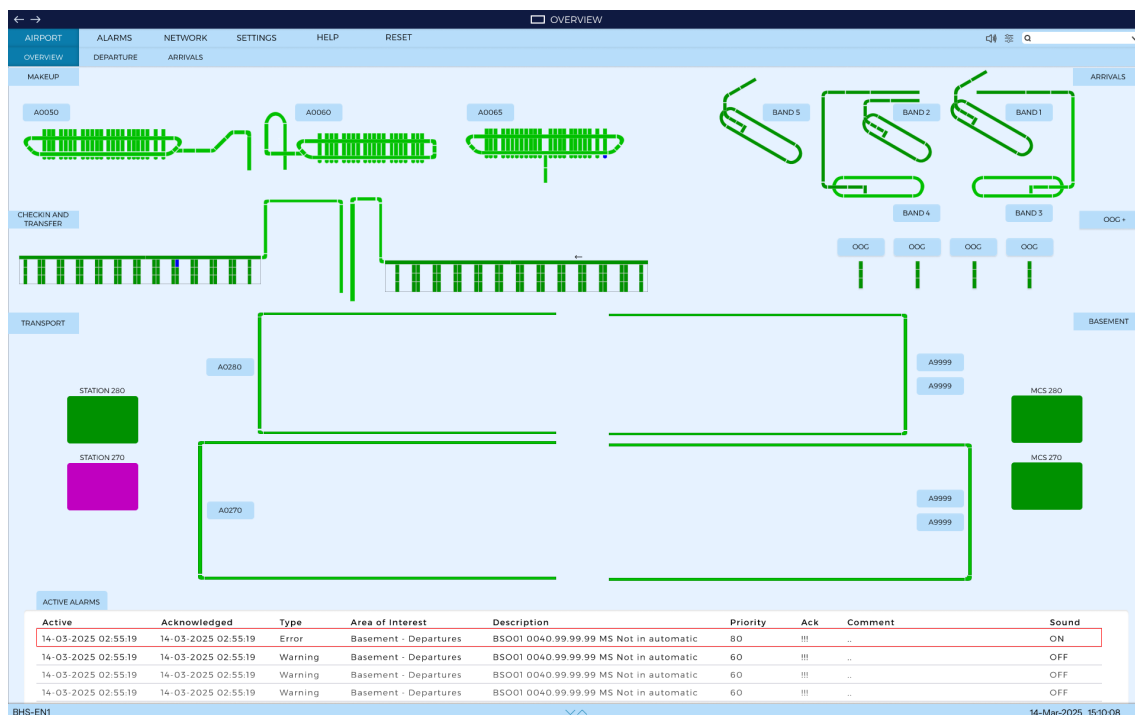


Figure 4.9: A prototype for the page "Overview"

Figure 4.9 showcases a prototype of a new overview screen to the SCADA system. The general changes were:

- Removal of the "Airport" screen
- Standardise fonts, sizes and icons
- Change the colour scheme
- Standardise blank spaces and grids
- Create smaller sequences for commonly used functions
- Hide unused functionality
- Add the arrivals map to the overview

As mentioned in the previous sections, the participants liked the overview screen. One of the most common sequences the participants did during observations was to press "Airport" and then "Overview". As can be seen in Figure 4.7 this sequence is noticeably not understood by the users displaying high occurrences of themes 4, 5 and 6. To make this more effective, the prototype switches to overview directly when pressing "Airport". The only function the "Airport" view had was a big button for departures, which they can still get to by pressing "Departures" to the right of "Overview" in the subheader. This was identified by the header being described as generally confusing and the layout being critiqued during the interviews and observations.

As seen in Table 4.2, during interviews participants commented on the overall system design and that it felt cheap. In Figure 4.7 themes number 4 and 6 are individually present in thirteen of seventeen UI elements. Due to this feedback, the prototype showcases an overview with standardised fonts, sizes, and icons. There is now only one font, the sizes are 16 for the current screen, 14 for the header and footer, and 12 for the main content domain. The detailed view headers have a font size of 14, sub headers are bold with size 12 and text is size 12. Icons are standardised to assist new users in learning the system with **habituation** from other systems.

On the same note, blank spaces and grids are implemented to give a more clean overview. This is also meant to mitigate users being unsure of where things are located, as theme 4 is common for the overview. As seen in Figure 4.9 the map section tabs are in line with each other within each section and all sections and buttons are dividable by 40 pixels in width.

Unused functionality, such as the "amount of screens" icon is hidden and could instead be displayed in e.g. settings. This is to not overwhelm the user with irrelevant information. This goes with theme 4 as well, since unused functionality easily creates an overload for users.

When comparing the current system to the prototype one of the most visible changes is the change of colours. As a participant stated in about the global UI in Table 4.2, the system could be developed more. As stated in Section 2.3.7 different choices give different effects to users. By increasing the contrast of the colours and change to a bright yet calm colour theme the hope was to give the system a more modern and developed feel. The current system is used side by side by other systems which have either lighter colour schemes or a dark blue background. Visiting the airport company's website it is possible to deduce a mostly blue colour scheme. Seeing the colours of other simultaneously used UIs and the company's thematic colour scheme, a choice was made to use a light blue colour scheme. This was then used to change and standardise the colours for the prototype.

Another sequence which was commonly used during observations was to see and send bags to another destination. Therefore four buttons were created called "Station 270", "Station 280", "MCS 270" and "MCS 280". When pressing these big buttons the users gets a pop-up or sidebar displaying the details of that unit. This saves the user from a sections map and needing to press a tiny rectangle within the map which was a problem found throughout the interviews identified as codes 9 and 16 in Table 4.1. The colours of the big buttons are the status colours of the units.

Lastly, for Figure 4.9, the current overview of the system only displays the

departures. Arrival tracks are added in order to get a full overview, also detailed screen to view and operate all arrival tracks should be implemented into the SCADA system. This change was caught as a direct user feedback to make these more clear as shown in Table 4.2.

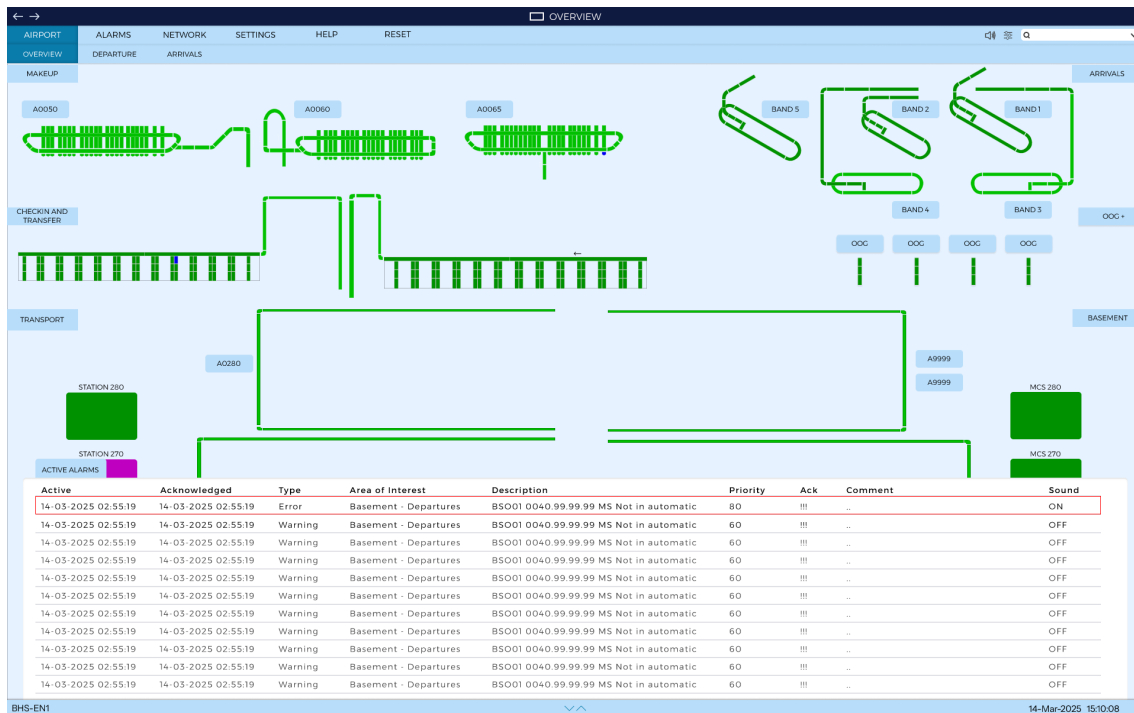


Figure 4.10: The redesigned scroll function for alarms

An existing feature for the current system was to press the arrows in the bottom centre of the screen to showcase more alarms while staying on the current page. This was redesigned featuring a scrolling function. This is meant to remove some of the uncertainty around the functionality of the error bar found in the thematic analysis.

4. Results

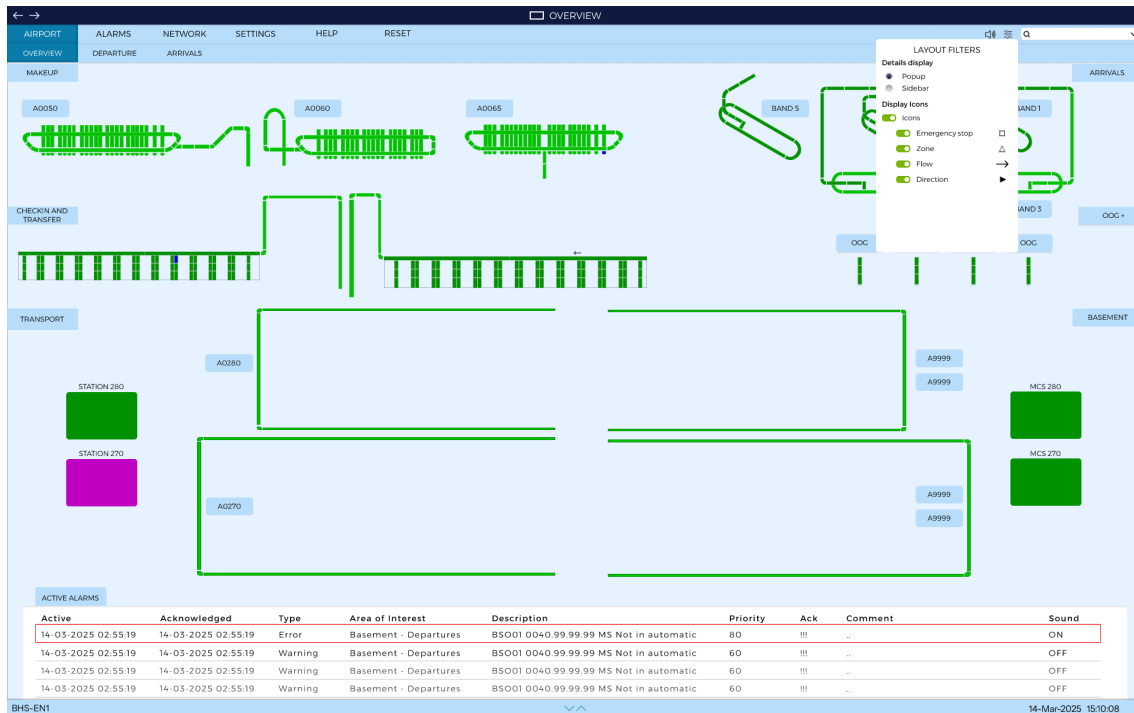


Figure 4.11: The new layout settings tab

During the observations and interviews the participants had a wish to customise the layout, display of icons and choosing between sidebar or pop-up for to display details. Therefore, the prototype showcases a layout menu by the search bar. This did exist within the current system to some extent, but the icon was not a standard icon and only to display all or not to display any icons on the map. During the interviews it became clear that users did not understand that back and forward arrows and icons display functionality already existed due to its design.

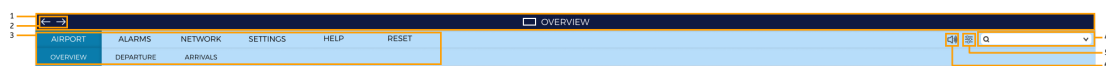


Figure 4.12: A detailed overview of the header

The modal panes pattern for the header was kept. The header was also standardised with grids and more commonly used icons. This was found to be a problem characterised by the codes "critique of layout" and "different hit-box sizes" in Table 4.1. As seen in Figure 4.12, pointer 1 the display of current system was moved to the top of the page and the icon, which was a star, was changed to a screen icon. This is to ensure that the end user understands what the system displays. During an interview, an end user requested the system to show which screen was displayed. This was showcased in the current system as well, but it was not clear.

Pointer 2 showcases the back and forward icons. During the observations, it became clear that the end users use them, but they were not in a common place. Since it is common, for example, for web browsers to have them in the top left corner the prototype has them there instead. This is to ensure **habituation** for new users.

Pointer 3 showcases the main menu. Using a grid of equals and big buttons they become more clear. The settings tab was moved to be between network and help. During the observations it was noticed that the most commonly used tab was airport(overview), second to alarms, therefore, they are furthest to the left. Network also involves the system and is therefore beside airport and alarms. Settings and help involves UX and are therefore grouped, and lastly reset is furthest to the right to not be unnecessarily pressed. This was to mitigate some of the issues behind theme number 6 by increasing separation and visibility.

The search bar (Figure 4.12.4) in the current system has the functions of writing specific unit numbers and scrolling through them. The change here is to be able to write the beginning of a unit number and display only those within the drop-down. The search bar design is also standardised and compared to common websites such as Google. This was changed for the prototype due to themes 4 and 6, since users displayed a dissatisfaction with the current capabilities of the search bar.

Lastly, pointer 5 and 6 are changed to more standardised icons. No.5 is to turn on and off the sound of the system and no. 6 to display the layout settings menu. As stated before, the capability of the system to turn on and off the display of icons did exist, yet only one user during the interviews knew this. By standardising the icons the users can more easily understand what the system is capable of. In connection to theme T4 from Table 4.1: I don't know what things do in the system.

4.7 ACM validation

In this section the ACM code of ethics [16] will be applied to the process to ensure that did not fall out of line or promote anything that is harmful or dangerous.

- **1.1 Contribute to society and to human well-being**

This is hard to apply to this project as the method itself is not applicable to the larger public. However, special care see chapter 4.7 has been taken in order to not spread unnecessary information and to keep confidential information secure.

- **1.2 Avoid harm**

As mention in the point above special care has been taken to preserve confidential information since the airport is a high stakes security object this has been done through avoidance of Google services for storing documentation and instead using network attached storage as well as having the report and artifacts be checked through by the company.

- **1.3 Be honest and trustworthy**

Documentation of the design process has been made in a way where decisions are traceable to specific interpretations of the data gathered through interviews, observations, and surveys. This is to ensure transparency and traceability for further development of the features.

- **1.4 Be fair and take action not to discriminate**

Accessibility has been taken into account when deciding on colours and sizes of objects. However, since the study's participants were rather homogenous, feedback and data has only been gathered from these people. The effects of

this are later discussed in chapter 5.4.

- **1.5 Respect the work required to produce new ideas, inventions, creative works, and computing artifacts**

The process of redesigning was based on the previous documentation and product the company used. Thus, most artifacts were kept from the previous design, respecting the work done by the previous company. The team has also been working closely with the company ensuring that their creative and innovative ideas were heard and highly valued.

- **1.6 Respect privacy**

Special care has been taken to take privacy into account when gathering data for the re-design discussed in section A.

- **1.7 Honor confidentiality**

This was discussed in point 1.2 avoid harm as confidentiality is a part of the security measures taken by the airport.

4.8 Validation Interviews

The validation was done by asking the participants to try the prototype and think aloud what they liked and disliked about the prototype compared to the current system. After testing it themselves, changes not visible in the prototype such as the new requirements 4.5 was explained to the interviewees who then had the chance to give feedback on these.

After receiving specific feedback during the validation, the screens were altered and they were directly shown to the user again, to make sure that the validation was understood correctly.

The feedback on the prototype was overall positive. All participants said that the prototype looks more neat than the current system. Standardisation and a higher contrast of the overall system was appreciated, yet some participants wanted a higher contrast for the map colours.

The feedback was as follows:

- Standardisation of icons, colours, fonts, and spacing makes the system easier to use and understand.
- The sound button for alarms is good.
- The shortcut buttons for the manual coding stations are a good addition, but perhaps a little too big.
- It is good to have a map overview that consists of both departure and arrival tracks.
- The new system overall is easier to see due to the higher contrast.
- "Airport" should be in the top left corner.
- Add some sort of button to be able to select multiple desks at check-in. Currently, there is only one or all that can be selected.
- The inclusion of keyboard shortcuts is appreciated, and the f-row should correspond to the navigational buttons.

4.8.1 Feedback and Themes

The general feel of the prototype was well received, and comments such as "Neat" and "Looks better" were made during the validation. When directly asked about the new standardisations of the layout, the users said that they noticed and liked it. This satisfies themes 4, 5, and 6 in Figure 4.7 as previously stated in Section 4.6.

Regarding the colours the users did as anticipated appreciate stronger contrast and asked for it in the map colours as well. This was not changed during validation due to scope constraints, yet is an important note for further work.

The removal of the "Airport" screen and letting the user directly go to "Overview" was well received during the validation, and this enhances theme 4 from Figure 4.7.

When directly asked about the removed unused functionality, the users appreciated it, since it made the view clearer overall. Yet, they stressed that some functionality, such as network, is rarely used and not completely unused. It is worth noting to be careful not to remove functionality too quickly. This agrees well with themes 4, 1, 3, and 7 from Figure 4.7.

Changed functionality, such as the "Current view" tab and the layout icon, was directly asked about. Some of the participants were surprised to hear that the functionality had previously existed, but were positive to see that it was clearer. This corresponds well with theme 6 from Figure 4.7.

The added functionality of the direct buttons for a detailed view of the stations and MCS's was appreciated since it shortened the sequencing of an often repeated task. This corresponds to themes 6 and 8 in the Figure 4.7.

4.8.2 Changes made

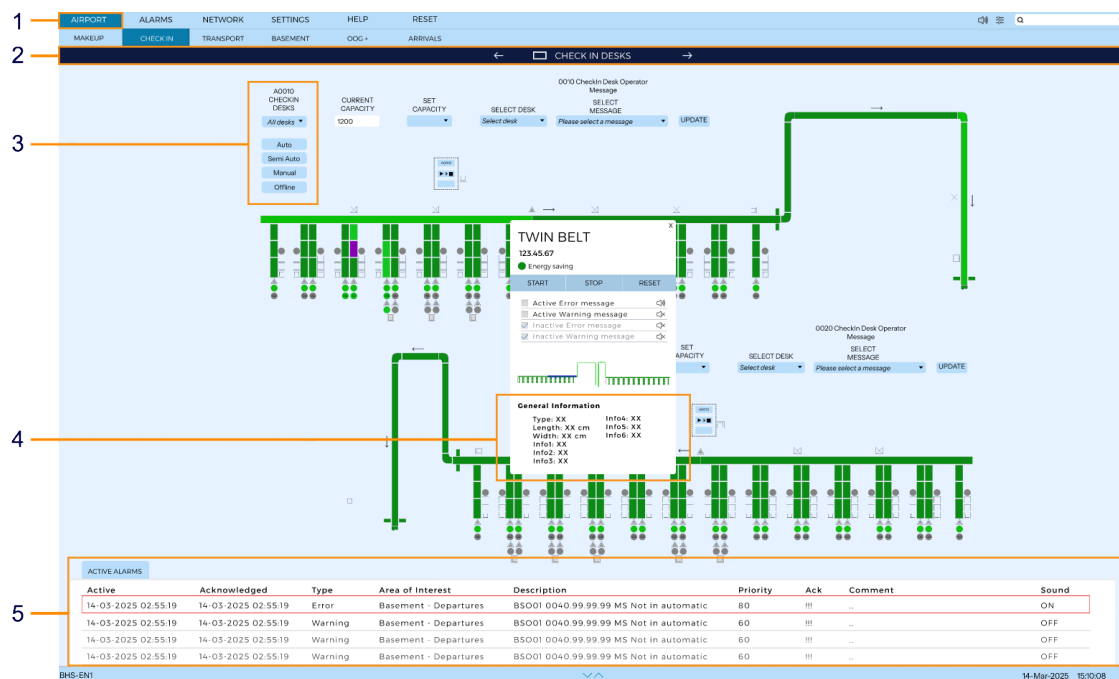


Figure 4.13: The prototype UI for check-in after validation

4. Results

Feedback from the validation interviews changed the header, since one user was adamant that the airport button should be in the top left corner. This was so that it would be easy to just drag the mouse all the way to the corner to get to the overview. In Figure 4.13 annotation 1 shows that "AIRPORT" is displayed at the top left corner and Figure 4.13. Annotation 2 is moved below the top menu to still display what is shown on the screen. This would further enhance theme 1 in the Figure 4.7.

In Figure 4.13, annotation 3 displays another change after validation. An added feature was, in the Airport → Check in desk area, to have a button to be able to select several desks at once. In the current system, the user can only select mode for one desk at a time or for all desks. The drop-down menu makes it easy for users to mark one, several, or all check-in desks and change modes. This would further enhance theme 1 in the Figure 4.7 for the check-in view, as well as lessen the sequencing of the task at hand.

In Figure 4.13, annotation 4 shows a change in the detailed view of a map unit. During the validation, a participant stated that the detailed overview also should contain detailed information regarding, e.g. its size, motor type, when a belt was last changed, and so forth. This could either be done by having standardised information as seen in the figure or by letting the operating users add specific information in a "comment section" of the detailed view. In the current system this does not exist, the information is instead accessible in other forms like separate documents. This addition concurs with theme 6 in the Figure 4.7, since users would know faster where to find detailed information for the maintenance of the physical units.

In Figure 4.13, annotation 5 displays the alarm list. The fact that it was possible to pull it up over the map was generally well received, and the sound button on the right was also appreciated.

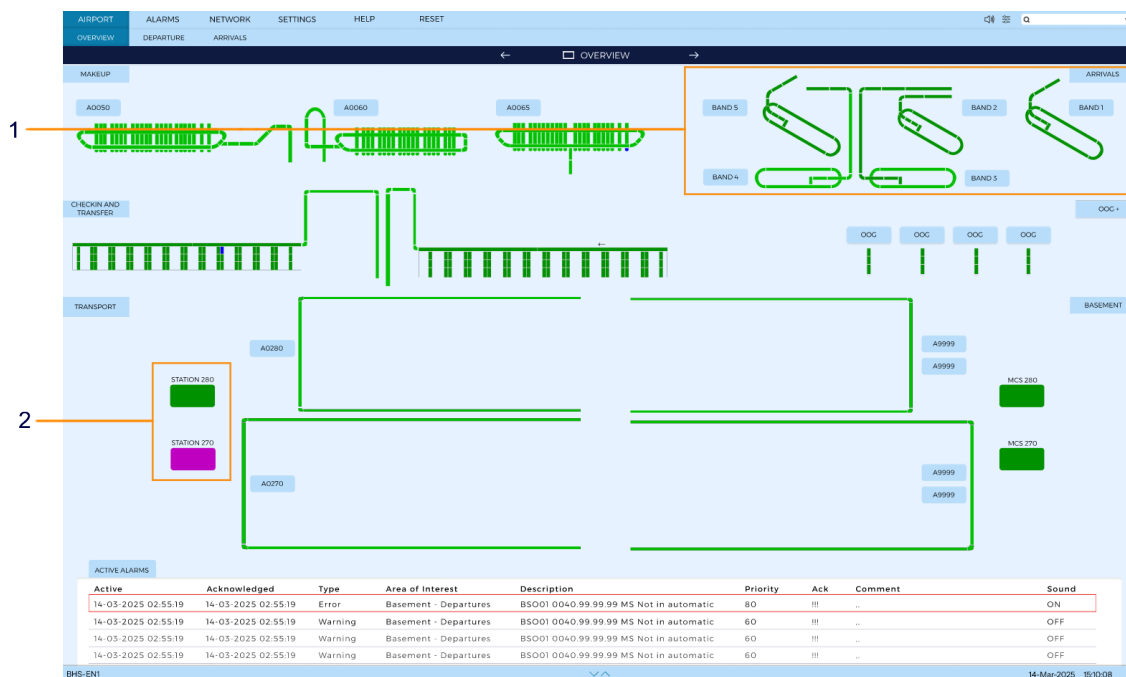


Figure 4.14: The prototype UI for check in after validation

In Figure 4.14 annotation 1 displays the arrival tracks. Having this in the overview was well received and corresponds to theme 6 and 2 in Figure 4.7.

In Figure 4.14 annotation 2 displays the big buttons for MCSs. These were changed in size after the validation. Still following the big button pattern, yet not overly big as in the first prototype. This concurs with the starting point of the validation, that the users enjoy more white space to get a more neat feel of the product, as well as not being overwhelmed by a complex system.

5

Discussion

This chapter presents a reflective discussion on the design process, research findings, and limitations encountered during the project. It outlines how data gathered through observations, interviews, and surveys informed the design decisions, and examines the impact of contextual constraints such as security restrictions and a limited user base. The chapter also addresses the implications of the study's findings for the company's future and provides a summary of the project's outcomes in relation to the original research questions. Together, these sections offer a comprehensive view of the project's strengths, challenges, and contributions to the development of more user-centred SCADA systems.

5.1 Impact

While this thesis does not present any new groundbreaking results in User Experience and Requirement Engineering, it demonstrates how established methods, in respective fields, can be successfully applied in a real-world industrial context. By following a structured process and documenting well, this project showcases a practical example on how to conduct a user-centred design study within the constraints of a bachelor's thesis.

This thesis may serve as a valuable resource for future students, especially those who aim to explore UX and RE in real-world settings. Through the creation of a comprehensive study design document and a systematic application of entrenched evaluation methods, this thesis provides a replicative workflow that can help guide similar student projects. This includes a strategy for conducting fieldwork, collecting data, and translating said data to actionable design decisions and functional- and non-functional requirements.

Additionally, this thesis integrates ethical considerations in UX and RE work, showing how the ACM Code of Ethics can be used to evaluate and guide responsible system designs.

Finally, in addition to academic relevance, this project had a direct impact on the collaborating company. The company expressed great satisfaction with the final result, highlighting the usefulness of the proposed design and the extended requirements. The result of this project may support future development and/or as a tool for communicating with system vendors. The final prototype and analysis offer insights that could lead to improved usability and user satisfaction.

5.2 Insights Shaping the Redesign

The redesign of the SCADA system was guided by principles of usability and UX patterns, with a focus on addressing user pain points identified during the study.

The observations and the open-ended interview questions revealed many user pain points, and even a few design suggestions were directly formulated during this data collection process. However, unexpectedly, when the interviewees were asked directly about a particular section or implementation, they often showed content with the current design. One such example was found in the navigation bar: all participants clicked the "Airport" tab only to get to the "Overview" page, and never used the "Network" or "Safety reset" tabs, suggesting that the "Overview" tab should be in the navigation bar and the removal of the "Airport", "Network", and "Safety reset" tabs. Nonetheless, when asked directly if they thought the navigation bar had a reasonable layout, most were content with how it looked. It was clear that the more open the question, the easier it was to uncover meaningful requirements and actionable design insights.

As expected, the validation interviews revealed problems that remained unaddressed and also some new problems that had appeared in the prototype. These problems were addressed in the final version of the prototype.

Overall, the process emphasised the value of combining open-ended user input with observational data to reveal actual usage patterns and overlooked pain points. While users might express satisfaction with a specific section or implementation when asked a closed-ended question, their actions and words when speaking about the entire system often suggested otherwise, underlining the importance of not relying solely on asking closed-ended questions. Furthermore, the validation interviews showed that iteration is essential; Even as earlier issues were resolved, new ones emerged in the prototype. This iterative approach was important to refining the design and ensuring that the improvements addressed real user needs rather than assumed ones.

5.3 Effect of limitations

There were a few limitations to this project due to a set of factors which were beyond control of the writers. The major ones were: airport security, the size of the division studied and access to documentation.

The issue that affected the outcome the most was the size of the division. There are only about 19 people who work at the baggage handling technical division at the airport studied and these are the only people who use this system. Most of these people have also worked at the company longer than the system itself has existed. This means that the variety of users was limited leading to an inability to compare perspectives effectively. One user who had never interacted with the system was interviewed but the format turned out to not be conducive to gathering any significant amount of data from that person. The ethical implications of this will be further discussed in 5.4.

Due to the aforementioned small size of the division the quality of the data in

the UEQ survey was compromised. It would still have been useable had the staff had a unanimous opinion but answers varied a lot from user to user. This made the answers hard to apply and interpret. The conclusion drawn from this was that the workforce was split on the quality of the software. Adding an open ended question at the end of the survey might also have given better data.

Another limitation was the security of the airport. This presented issues both on an access level where entering the airport was restricted to booked meetings and therefore using the software where also limited to these meetings. This also mean that evaluation was strictly limited to the people working at the the baggage handling division which expanded the issue of the small workforce.

To mitigate the issue of access to the airport itself a request for documentation was made to the airport early on. This was however hard to acquire due to the security implications of handling and storing these documents. Some of the documentation received was also of another airport in Sweden.

5.4 Ethics

The small workforce that works with the studied software leads to some ethical considerations having to be discussed, the main one being demographic variety. Most of the people working with the system are men above the age of 40 with a high self-evaluated computer knowledge. Having a non-diverse user base in a study can lead to a biased result [37] and thusly a design that is inapplicable to a larger audience. However, the study does cover a majority of the current users. The ability to evaluate the system with a wider demographic outside of the airport was also limited due to security.

There are many facets of ethics that arise when working with a user centric study with the factor of informed consent being one that appears often. It has been proposed in research around informed consent that both internal (workers at the airport operations company) as well as external (workers at the handling companies) should have the same data protection as the contracts that workers have signed as a term for their employment might not cover documentation made for research [38]. Therefore we have concluded that the same informed consent form or at least similar ones should be signed by all.

In addition it is important to protect the workers when conducting a study where criticism and evaluation of the system is central. The largest part in the protection is to only include the results, discussion and conclusions, excluding complete individual answers. Creating an environment where the workers feel safe to express opinions and concerns not limited by fear. This can be due to worries around job security as well as income stability which can arise in regard to non compliance during a study from a third party that is still sponsored by the employer [39].

Another part of research ethics is privacy or how one handles the data gathered. This is in part regulated by the above mentioned informed consent form however there are still relevant aspects to consider during the general proceedings of the study. The European Union Agency for Network and Information Security [40] argues that personally identifiable data should not be the only type considered in

terms of privacy since this does not protect groups which can later identify the person. This is considered for the project's management of participant data pertaining to larger groups such as shift time and age.

In an ideal world all data gathered could be represented in the report making descensions traceable. However some of the personally identifiable details, such as age, were needed to inform recommendations and conclusions. Therefore a decision was made to represent most data as analysis with some text out-takes to represent the method of analysis made.

The ability to withdraw ones answers was given in the informed consent contract for all participants however this is not possible for the surveys as these are anonymised by default meaning that answers cannot be linked to a person. Therefore the group is unable to delete these upon request of the respondent. Interview protocols record names so these are able to be removed although this will not be done upon request of the company just the interviewees.

Finally, working with an airport and especially monitoring of goods that are going onto planes gives an obvious point of societal security and ethics. At every step of the process we have to take the security of passengers and the airport at large into account. Hopefully the product will contribute to a more secure environment by increasing the usability of the products used to handle the transfer and monitoring of the mentioned goods.

5.5 End result

The research questions stated at the introduction of this paper will be answered in the following subsections.

5.5.1 Needs and wants

The needs of the end users of the SCADA system mainly centres around the use cases already documented in the airports documentation with a few deviations such as the ability to use quick commands which has been implemented in the final prototype. The wants centre around using the software as a means to an end which can be seen in the feelings of confidence and domain knowledge present in interviews and observations coded in Figure 4.7. However, it seems there is currently a feeling of lower quality of software illustrated in the quotes about the global software in Table 4.2.

Lastly, it can be argued that the wants and needs of the users of this system might be secondary to its functionality as that is critical for the airport to function as a whole. However, the specifics of interaction can be changed for the better.

5.5.2 How can the company evaluate UX

The methods used in the study, although effective according to the validation, can be improved. The most valuable information gathered for the re-design was the interviews. This is illustrated by the lack of observations in Table C.1 as well as

the little information gained from the survey. The method of participant observation has also been criticised as being slow relative to more active research methods although it gives a deeper understanding of the context the population is in [41]. For future evaluations it is a good idea to use interviews for gathering information about changes in the experience. However, the interviews took quite a bit of time, but on the other hand there is no use in any quantitative data gathered as the pool of possible users is so small.

5.5.3 Patterns and best practices

There are several ways of using patterns to solve specific user issues. A solution presented by Segerståhl and Jokela [42] suggests that patterns should be regrouped into problem areas and then used to solve specific issues users have with the current design. This, however, does not work with the patterns presented in the background of this paper as they are grouped more into interface and interaction categories. Another way of using patterns is to map it to some sort of usability property and then figuring out what needs to be improved in that area [43]. These two approaches have a user-centred approach in common, whether that is problems or tasks.

The analysis of the patterns used shows that many patterns are implemented in the current system- However, the interviews still found dis-content with many aspects of the system. This can be due to the lack of input employees have had towards the developer.

Best practices exist within the UX and UI development process and an important impact of these is shown with the prototype. Standardisations and to use patterns for specific purposes to satisfy user needs and wants creates a more well received UX. This has also been proven in other studies according to Fachrizal et al. [44] and by Wijaya et al [45]. Goodman et al. discusses in their paper that best practices inhibit innovation, yet they are a good framework to have in order to know when to break them on purpose [46].

5.6 Need for further research

Further research on this specific project could include additional rounds of observations and interviews with the rest of the workforce. It could also involve more iterations of validation and redesign of the Figma prototype. An interactive digital prototype could be developed and tested by the workforce, with objective data such as task completion time and error rates being measured and compared to the current system. Eventually, the project could be integrated into the current system, with the new interface and additional requirements incorporated into the existing documentation. It could also be valuable to conduct studies to observe how the new designs impact user satisfaction, operational efficiency, and system safety over a long period of time.

Additionally, more advanced elicitation methods could also be explored to complement traditional approaches such as surveys, observations, and interviews. For instance, eye-tracking technology could provide insights into users' visual attention, helping to identify interface elements that cause confusion or delay. Likewise,

statistical analysis of user interactions, including click patterns, navigation paths, and mouse movements, may uncover usability issues that traditional methods might overlook. By combining these advanced techniques with conventional ones, a more comprehensive understanding of user needs could be developed, leading to more informed design decisions.

5.6.1 Industrial use of colours and maps

During this project an attempt was made to look at mapping colours and how well the users understood what they saw on their map view. Due to time constraints it was not possible to further research and implement this into the prototype. However, the participants were still asked to explain the map colours and symbols as seen in section 2.3.7.

The map view with symbols and colours as seen in figure 4.1 is used every day in the current system and further research could enhance end users' daily experience with the system. For further reading there is research on both colour theory [47] [48] [49] [50] as well as colour usage in industrial systems [51] [52] [53]. This could be used for further studies and implementations.

5.6.2 Broadening and Comparisons

Further research on other SCADA systems could involve the use of different approaches to achieve similar goals. Such approaches could include, but are not limited to, developing low-fidelity prototypes early in the process, applying alternative methods for observations and interviews, using personas, or applying different types of experiments to elicit requirements and inform design decisions. Another important area for future research is accessibility. Further studies could investigate how well different SCADA systems or a particular SCADA system accommodate users with various types of disabilities or impairments, such as colour blindness, visual-, motor-, or hearing impairments.

Lastly, broader research directions could look into how other SCADA systems in different airports or countries are designed, to compare practices and user expectations in different cultures and organisations. Another valuable direction could be to examine how operators interact with SCADA interfaces under simulated high-stress or time-critical conditions, in order to better understand how interface design impacts decision-making and error prevention. Finally, a cost-benefit analysis could be conducted to evaluate the long-term value of improved usability in SCADA systems in terms of reduced operator error, training time, and increased operational efficiency.

6

Conclusion

This study explores how UX and RE methods can be used to improve usability in a baggage handling SCADA system. Key takeaways reveal a paradox between content and dissatisfaction with the design of the system.

Users confirm the system's operational reliability, a sort of "I can complete all necessary tasks" -satisfaction. They also show a content with the design and usability when asked about specific sections and functions. Notably, dissatisfaction emerges only when users reflect holistically on the system, which is uncovered through open-ended interview questions and participant observations where they criticise unintuitive workflows when interacting with specific features.

Interviews, when analysed through thematic coding, prove to be the most effective way to elicit requirements, uncover insights about design, and make informed design decisions. In contrast, the UEQ survey prove lacklustre and offer little value to the formulation of requirements and the design of the prototype. Perhaps constructing a custom survey, tailored for this project, would prove to be more fruitful.

In the prototype validation interviews, the feedback is generally positive. The prototype is perceived by testers to be more organised and visually neat. Participants appreciate the standardisation of icons, fonts, colours, and spacing, as well as the addition of new interface elements such as shortcut and sound buttons. The higher contrast of the colours is also highlighted as an improvement. However, some negative feedback was also received, and new issues and suggestions emerged. Based on this input, the prototype was revised to better address the participants' concerns.

Moving forward, additional rounds of user interviews, observations, and prototype validations would further strengthen the findings. It would also be interesting to use more advanced elicitation techniques, such as eye-tracking technology and statistical analysis of user interactions. Should a new design with a stronger focus on usability be implemented, studies to examine its long-term effects would be of value.

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A

The informed consent contract(Translated from Swedish)

You are asked to participate in a user study. Before you participate it is important that you know why it is conducted and what you are going to do.

Why?

This study will gather data to be used to create Requirements and a UX design to be used in newer iterations of the system. The process is meant to increase the user friendliness of the system.

Process

There are three parts to this study

- Observation
- Interview
- Questionnaire

Observations

Observations will be conducted during your workday by one or more of our group members. We will take notes of the processes you are going through and if you encounter any problems. Observations will take approximately one hour and we will do our best to not interrupt your work.

Interview

We will conduct interviews with those of you who part take in the observations. This will be done after each observation. Interviews are planned to take forty minutes. The interviews will be recorded (audio only) and notes will be taken.

Questionnaire

We will also give out a paper questionnaire to a larger part of the workforce where usability will be evaluated through points.

Data handling

All stages in the process will be documented anonymously and we will limit the amount of data that can be used to personally identify you in any way and especially make sure that the data is not shared outside of the group working on the project. We will not share dates exactly and only note general time spans such as "day" or "night". Eventual names in the data will be anonymised after interpretation of the data and if pictures are taken they will not include any people.

When it comes to forms, these will not gather any personally identifiable data

The complete originals of the data will not be shared with anyone outside of the working group and after the publication of the report it will be destroyed completely. The deadline for data destruction is 01/07 - 2025.

What are you agreeing to?

By signing this contract you agree to the conduction of this study and that the data we gather will be used to make the designs and requirements for the system and then destroyed by 01/07-2025.

non-mandatory

We want to remind you that participation in this study is non-mandatory and that you can decide to retract your answers at any time. Upon retraction, data that is directly traceable to you will be destroyed.

FOr questions, please contact us via email: repsac2002@gmail.com

B

The interview and observation protocol (Translated from Swedish

Observation and interview

19 Mars 2025

Participant name:

Date and time: March 19 2025

Contents

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1 Observation notes

Task:

Notes:

|||||||

Positive:

|||||||

Negative:

|||||||

2 Interview

2.1 Background information

- Experience with the SCADA system.
 - New / In training
 - < 1 years
 - 1-5 years
 - > 5 years
- Shift
 - Early (T or T5)
 - Day-pass (D)
 - Evening (S eller XS)
 - Night (SS)
- Age
 - 18-25
 - 26-35
 - 36-50
 - > 50
- Computer knowledge

- Beginner
- Intermediate
- Expert

2.2 Contextual Inquiry

- Navigation
 - What do you do when you want to look closer at a specific track, for example the one going up from the basement to no. 65?
 - A colleague asks you to reset a track, for example, a split towards the MCS, what do you do?
 - You want to send a message to desk 32, what do you do?
 - Bags cannot go on a specific track because of maintenance, how do you redirect traffic from M17?
 - You are supposed to start arrival track 4 manually, how do you do that?
- Error messages
 - What do you do if 50 stops and throws an error?
 - what do you do if an SBD stops and throws an error?
 - A Height error is thrown, what do you do?
 - Someone pulls the emergency stop in arrivals, what do you do?
 - En väska väntar i MCSen i gamla källaren och systemet larmar, vad gör du?
 - A bag is waiting in the MCS in the old basement and the system throws an error, what do you do?
- Understanding
 - The top menu has many tabs with subcategories. Can you explain what they mean and which of them you use?
 - Can you explain the colour codes in...
 - * The tracks?
 - * The error messages?
 - Look at the top three error messages, what do they mean?

2.3 Questions

2.3.1 About SCADA

What do you think about the layout of the SCADA system?

What do you think about the layout and format of the status/error messages?

How long did it take for you to become comfortable with the system if you do feel comfortable with it at the moment?

Do you feel like you use the system to its full potential?

Are there any functions that you consider optimal or critical?

Do you use all of the system's functions?

If no, what functions do you not use? Why?

2.3.2 Design patterns

Safe exploration

Is there any page you don't feel comfortable navigating?

Tell me about a time you clicked in the wrong place, what happened? Did you solve the problem?

Instant gratification

Do you feel like the program is responsive?

Change in midstream

There are two errors thrown, you are working on one but want to check on the other. How do you navigate back to the original error?

Habituation

Are there any macros in the system that you use?

Do you miss any macros?

Can you use the software without a mouse?

Visual hierarchy

Have you ever forgotten to take care of an error? How and why?

Visual framework

What is your opinion on the software's design?

Do you feel like it's cohesive?

Is something unclear or unreadable?

Navigation

What do you think about the order of the navigation bar?

Conveyor colours

Look at the colors in front of you. What color should correspond to what status? »Show pictures«

Have you seen all the colours appear in the system?

Symbols

Are there any symbols here that you do not recognize?

2.4 Open question

Is there something we have missed or do you have any additional comments?

3 Dictionary

SBD - Self baggage drop

C

Extra information from the thematic analysis

ID	Computer proficiency (0-3)	Interviewed	Observed
P1	3	x	x
P2	3	x	
P3	2.5	x	
P4	3	x	x
P5	2	x	x
P6	3	x	x
P7	2	x	

Table C.1: Participants and their computer proficiency

D

The UEQ survey questions

Please make your evaluation now.

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unattractive
------------	-----------------------	----------------------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	--------------

This response would mean that you rate the application as more attractive than unattractive.

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember: there is no wrong or right answer!

Please assess the product now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	enjoyable	1
not understandable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	understandable	2
creative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	dull	3
easy to learn	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	difficult to learn	4
valuable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	inferior	5
boring	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	exciting	6
not interesting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	interesting	7
unpredictable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	predictable	8
fast	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	slow	9
inventive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	conventional	10
obstructive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	supportive	11
good	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	bad	12
complicated	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	easy	13
unlikable	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasing	14
usual	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	leading edge	15
unpleasant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	pleasant	16
secure	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	not secure	17
motivating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	demotivating	18
meets expectations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	does not meet expectations	19
inefficient	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	efficient	20
clear	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	confusing	21
impractical	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	practical	22
organized	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	cluttered	23
attractive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unattractive	24
friendly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	unfriendly	25
conservative	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	innovative	26

E

Pictures of the correct SCADA system

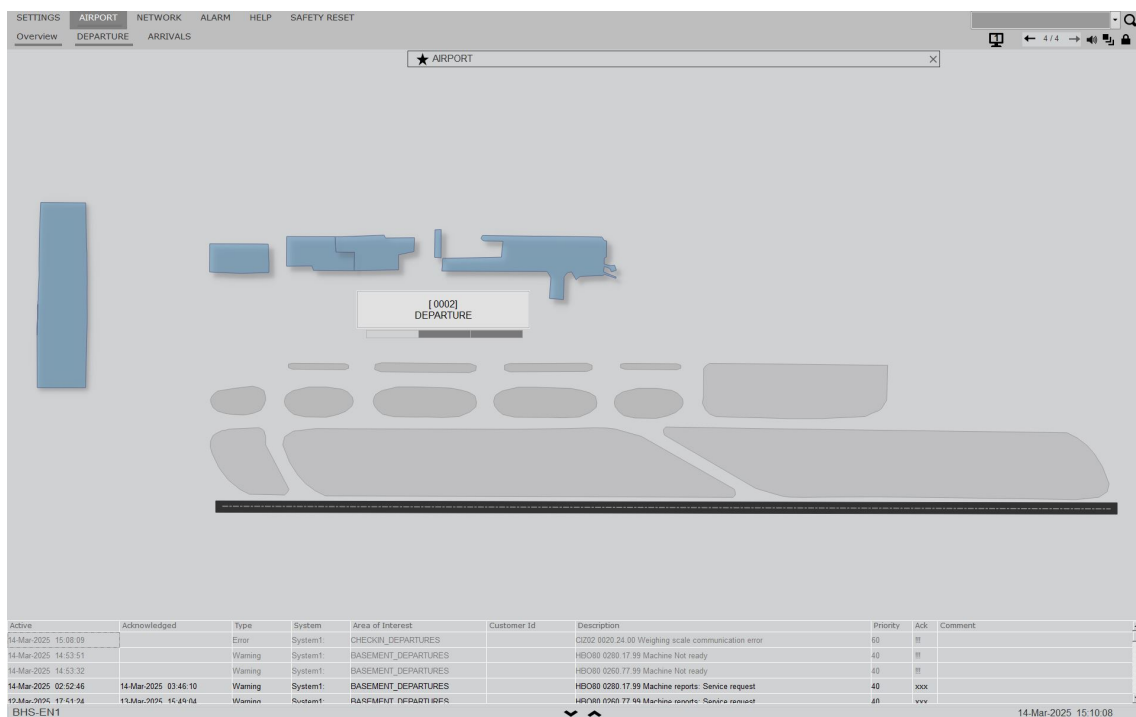


Figure E.1: The general "airport" page. Adapted with permission.

E. Pictures of the correct SCADA system














No.	Type	Colour indication	RGB
1	Safety stop		255,255,255 : 255,0,0
2	Offline		0,0,240
3	Error		255,0,0
4	Warning		255,140,0
5	Stopped		255,255,255
6	Stopping		255,255,255 : 0,192,0
7	Energy saving		0,145,0
7	Die back		255,0,0
8	Full		255,255,0
9	Externally Stopped		255,205,205
10	Not Connected		0,0,0
11	Started		0,192,0
12	Starting		255,255,255 : 0,192,0

Figure E.2: Colour choices for the visual operator feedback.

no.	Type	Colour indication	RGB
1	Safety stop		255,255,255
2	Offline		0,0,240
3	Error		255,0,0
4	Stopped		255,255,255
5	Started		0,192,0

Figure E.3: Colour choices for the status bar

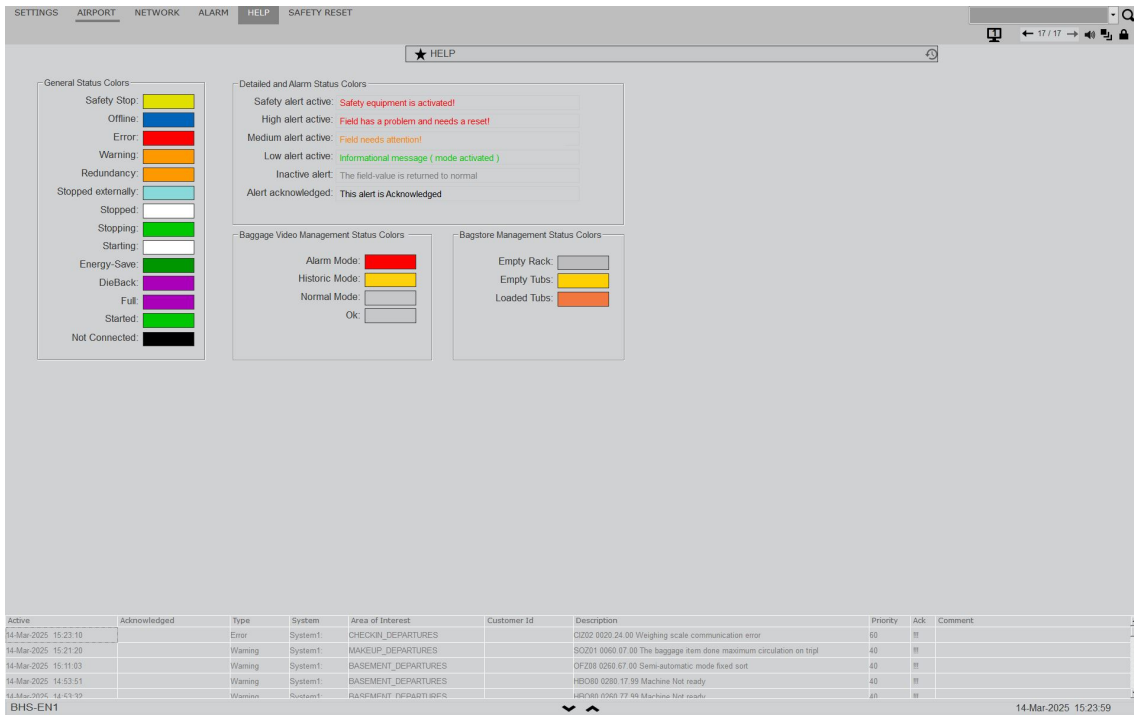


Figure E.4: The help page of the system. Adapted with permission